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MANAGEMENT AND ANALYSIS OF GIS DATA

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TECHNICAL MEMORANDUM 96.29
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Abstract

The development and application of GIS-based techniques for predicting changes in groundwater discharge and associated dryland salinity in the Loddon and Campaspe catchments in northern Victoria involved the assembly, collation and analysis of very large datasets. These datasets include surface elevations, bore hydrographs, streamflow and stream salt loads from a number of sources. The value of this effort is two-fold: (1) the analyses contain herein are the basis of the HARSD and WAVES modelling predictions as well as the geographic interpretation of remotely-sensed data, and (2) the error-checked database thus produced forms an ongoing resource to land agencies working within the Loddon-Campaspe system for further analyses. This technical memorandum serves as a manifest of this database, as well as presenting the myriad analytical results involved in salinity risk assessment under the Natural Resource Management Strategy project, Risk Analysis for Dryland Salinity Assessment, a collaborative project between the CSIRO Division of Water Resources and the Centre for Land Protection Research.

I. Introduction

A project funded under the Murray-Darling Basin Commission's Natural Resource Management Strategy, *Risk Assessment for Dryland Salinity Assessment*, and involving the CSIRO Division of Water Resources and the Centre for Land Protection Research, aimed to develop and apply GIS-based techniques to the modelling of groundwater levels and fluxes with respect to land use and salinity in the Loddon and Campaspe catchments in northern Victoria. The project was part of CSIRO's contribution to the National Dryland Salinity Program, whose strategy was to concentrate and encourage dryland salinity research in five focus catchments across Australia. The philosophical basis to this program was to develop, apply and demonstrate techniques suitable for wide employ across the extensive areas at risk to dryland salinity nationally.

Given the above philosophy, an approach based on geomorphological theory, limited process-based modelling and remote sensing was advanced in the dryland portions Loddon-Campaspe system; irrigation areas in the north of the system were necessarily omitted from consideration. Fundamental to this activity was the garnering, collation, error-checking and analysis of hydrological, hydrogeochemical, hydrogeological, and topographic information existing within a number of state and federal departments. The resulting database is of value not only to the analyses underlying the above project, but also to future investigations of the Loddon-Campaspe system. Thus, the database and analyses are themselves an outcome to be transferred to land management agencies, and this manuscript serves as both a detailed presentation of analytical results as well as a manifest to accompany this database.

The bulk of these data are associated with the GIS-based groundwater modelling approach known as HARSD (Hydrogeomorphic Analysis of Regional Spatial Data), and it is these data and analyses upon which this document focuses. The climatic and soil hydraulic data and inferences made in support of the WAVES water balance modelling are reported separately (Dawes et al. 1996), as are the AVHRR and LANDSAT-TM results (McVicar et al. 1996).

The very large number of analyses, while underpinning the groundwater modelling, preclude presentation in printed form. For instance, it is neither practical nor necessary to present the each of the 1500 bore hydrographs, numerous stream water and salt discharge hydrographs, or the water level maps, hydrogeomorphic classifications and flownets for the 40 subcatchments of the Loddon Campaspe. Nor is it feasible to examine every possible land management scenario and its effect on groundwater discharge and salinity risk. Rather, because the HARSD technique is developed and encapsulated within a GIS/database framework, the entire body of work is accessible

electronically, including results. More importantly, reanalysis and new scenarios are immediately facilitated within this framework. Thus, the outcome of the project has immediate value, but also provides a dynamic framework for agencies to develop and examine the potential impact on dryland salinity and salt loads due to new strategies for land management, or due to new information on system properties or behaviour.

II. Bore Hydrograph Data and Analyses

Bore data was obtained through the (former) Rural Water Corporation, and the (former) Department of Conservation and Natural Resources. Significant screening and collation was required to implement a consistent bore identification numbering system recognisable by state agencies. Clarification on this matter was provided by the HydroTechnology Database Manager.

Records for approximately 17,000 bores were identified and assessed for inclusion in the analyses. The elimination of bores located in the irrigation areas, as well as the selection of 1991 as the standard year for assessing water levels and water level fluctuations, meant that of the 385,000 annual time series (1,500 bores) potentially available, only 475 time series were used to develop regression relationships with surface elevation within hydrogeomorphic units (HGUs) or subcatchments.

Two issues arise with respect to the development of regressions between land and hydraulic head surfaces. The first of these is the arbitrary choice of 1991 as the target year for the water level analyses aimed at developing a hydraulic head surface, and the second is the arbitrary time scale of one year to derive the maximum and minimum water levels. With respect to the first of these, review of the 385,000 time series revealed that 1991 had the largest volume of available data. Secondly, the use of a one-year timeframe for water level assessment seemed an appropriate and natural compromise between length of record and minimising long term trends. All available datasets were used for the calculation of seasonal and long term water level fluctuations and trends as well as for recharge estimation, however.

The hydrogeomorphic units (HGUs) into which the region was classified are defined within the database described in Section VIII. It was originally intended that the landscape be disaggregated into the following combinations toward the development of unique regressions of surface elevation on water levels:

geology x catchment:	12 classes
HGU x catchment	18 classes
geology x HGU x catchment	108 classes
geology x HGU x vegetation catchment	216 classes

Clearly, there were insufficient bore records in total to support the regression analysis for all of the 354 classes above; indeed, for many of these classes, no observations on water level were available. On the arbitrary criterion that data from at least eight bores was necessary for this purpose, the classes were modified accordingly:

geology x catchment:	4 classes
HGU x catchment	5 classes
geology x HGU x catchment	5 classes
geology x HGU x vegetation catchment	5 classes

Preprocessing of Bore Data

The following is an outline of bore data preprocessing.

Key:

n	=	number field
char	=	character field
m.asl	=	metres above sea level
m	=	metres
(x,y,z)	=	all possible values for field
X.y	=	name of database <i>table.name</i> of field
X.min	=	summary statistic of a variable
class(x)=		number of elements in the classification

A. Attribute Specification

The following attributes were sourced and attached to each bore in the Loddon-Campaspe region:

1. Bore number **bore id(n)** {using new RWC bore number system}
2. Location **latitude (degrees)**
longitude (degrees)
3. Elevation **elevation(m.asl)** {as per DEM where not available}
4. Geology **geology(char)**
 al = alluvium
 fr = fractured rock
 gr = granitics
 sf = sedimentary formation
 vp = volcanics
5. HGU **HGU(n) = (1-9)**
6. Subcatchment **subcatch(char) = (Axe Creek,...,Upper Loddon)**

7. Vegetation **veg(n) = (1-2)**
 1 = old classification (1-2)
 2 = old classification (3-5)
8. Depth of well **Depth(m) = Aquifer.depth(m)**
9. Specific Capacity **SC(m³/m/day) = Aquifer.rate(lt/sec convert to m³/day)/Aquifer.drawdown(m)**
10. Hydraulic Conductivity **HC(m/day) = (1/SC)/(screen_fr(m) - screen_to(m))**
11. Salinity **Salin(mg/l) = Chemicals.tds**
12. Seasonal Fluctuation **Season = single cycle from wl.min to next wl.min**
Season.min(m) = Fluctuation.min {over entire record}
Season.max(m) = Fluctuation.max {entire record}
Season.fluc(m) = Fluctuation {each cycle in record}
- {incomplete years of record not included; years with less than 3 points excluded; seasonal fluctuation compared with precipitation for general correlation/error checking}
13. Long Term Fluctuation per bore, for entire record
- $$\text{Avg.Rise(mm/day)} = \left(\sum \frac{\delta p^n}{\delta t^n} \right) \frac{1}{n}$$
- $$\text{Avg.Fall(mm/day)} = \left(\sum \left(\frac{p^n_{\max} - p^{n+1}_{\min}}{t^n_{\max} - t^{n+1}_{\min}} \right) \right) \frac{1}{n}$$
- where: n = number of cycles recorded for bore
 pⁿ = water level for cycle n
 t = time
14. Seasonal Recharge **Season_fluc* aquifer specific yield**
 {per bore, entire record}
15. Annual Recharge Long term fluctuation* aquifer specific yield

For the calculation of recharge a specific yield table was constructed from published data (Heislars, 1992) and in consultation with DCNR personnel.

Geology	HGU	Specific Yield (SY)
al	1	0.1-0.2
al	2	0.08-0.150
al	3	0.07-0.100
al	4	0.06-0.080
fr	2	0.045-0.07
sf	1	0.05-0.08
sf	2	0.045-0.07
sf	4	0.035-0.06
sf	5	0.03-0.055
sf	7	0.02-0.04
vp	1	0.05
vp	2	0.045
vp	3	0.040
vp	4	0.035
vp	7	0.03

B. Statistical Summary

The following statistics were derived, based on the above data:

1. Geology:
 - for each geology class:
 - i. number of bores
 - ii. min/max/mean of bore depth
 - iii. min/max/mean of specific capacity
 - iv. min/max/mean of hydraulic conductivity
 - v. min/max/mean of salinity
 - vi. min/max/mean of Season.min
 - vii. min/max/mean of Season.max
 - viii. min/max/mean of Season.fluc/s
 - ix. min/max/mean of Avg.Rise
 - x. min/max/mean of Avg.Fall
2. HGU:
 - for each HGU class:
 - (i) to (x) as for (1) above.
3. Geology x HGU:
 - for each geology x HGU class:
 - (i) to (x) as for (1) above.
4. Geology x HGU x veg
 - for each geology x HGU x vegetation class:
 - (i) to (x) as for (1) above.

C. Contents of *Final_dc* Database of bore data

The following is an outline of the *Final_dc* database, showing the table name, in bold, followed by a description of the contents of that table. The database is in MS-Access format. Data regarding seasonal fluctuations are in a separate table. Any queries found as part of the database are not required in order to use the tables provided, and can therefore be deleted or ignored.

Final - by bore id - 475 records (by ascending order of bore id)

bore id	-	number
latitude	-	degrees South
longitude	-	degrees East
elevation	-	metres above MSL
geology	-	class
HGU	-	class
subcatchment	-	name
vegetation	-	class
season_min	-	metres
season_max	-	metres
avg rise	-	mm/day
avg fall	-	mm/day
season_trend	-	mm/year

Final - by geology - 475 records (by ascending order of geology then bore id)

bore id	-	number
latitude	-	degrees South
longitude	-	degrees East
elevation	-	metres above MSL
geology	-	class
HGU	-	class
subcatchment	-	name
vegetation	-	class
season_min	-	metres
season_max	-	metres
avg rise	-	mm/day
avg fall	-	mm/day
season_trend	-	mm/year

Final - by subcatchment - 475 records (ascending order of subcatchment then bore id)

bore id	-	number
latitude	-	degrees South
longitude	-	degrees East
elevation	-	metres above MSL
geology	-	class
HGU	-	class
subcatchment	-	name
vegetation	-	class
season_min	-	metres
season_max	-	metres
avg rise	-	mm/day
avg fall	-	mm/day
season_trend	-	mm/year

Recharge - 3347 records (by ascending order of bore id, then year, then specific yield)

Note: this file contains a number of records per bore, calculated over length of time series

bore id	-	number
year	-	yy
season_fluc	-	metres
season_trend	-	mm/year
specific yield	-	unitless
seasonal recharge	-	mm
annual recharge	-	mm

Seasonal fluctuation - 1679 records (by ascending order of bore id, then year)

Note: this file contains a number of records per bore, calculated over length of time series

bore id	-	number
year	-	yy
records	-	number of time series records
min of wl	-	metres
date of min wl	-	dd/mm/yy
max of wl	-	metres
date of max wl	-	dd/mm/yy
season_fluc	-	metres

Final - by geology - 5 records (ascending order of geology)

geology	-	class
bores	-	number of bores
MinOfSeason_min	-	metres
MaxOfSeason_min	-	metres
AvgOfSeason_min	-	metres
MinOfSeason_max	-	metres
MaxOfSeason_max	-	metres
AvgOfSeason_max	-	metres
MinOfAvg rise	-	mm/day
MaxOfAvg rise	-	mm/day
AvgOfAvg rise	-	mm/day
MinOfAvg fall	-	mm/day
MaxOfAvg fall	-	mm/day
AvgOfAvg fall	-	mm/day
MinOfSeason_trend	-	metres
MaxOfSeason_trend	-	metres
AvgOfSeason_trend	-	metres

Stats - by Geology x HGU - 21 records (ascending order of geology, then HGU)

geology	-	class
HGU	-	class
bores	-	number of bores
MinOfSeason_min	-	metres
MaxOfSeason_min	-	metres
AvgOfSeason_min	-	metres
MinOfSeason_max	-	metres
MaxOfSeason_max	-	metres
AvgOfSeason_max	-	metres
MinOfAvg rise	-	mm/day
MaxOfAvg rise	-	mm/day
AvgOfAvg rise	-	mm/day
MinOfAvg fall	-	mm/day
MaxOfAvg fall	-	mm/day
AvgOfAvg fall	-	mm/day
MinOfSeason_trend	-	metres
MaxOfSeason_trend	-	metres
AvgOfSeason_trend	-	metres

Stats - by Geology x HGU x Veg - 30 records (in order of geology, HGU, vegetation)

geology	-	class
HGU	-	class
vegetation	-	class
bores	-	number of bores
MinOfSeason_min	-	metres
MaxOfSeason_min	-	metres
AvgOfSeason_min	-	metres
MinOfSeason_max	-	metres
MaxOfSeason_max	-	metres
AvgOfSeason_max	-	metres
MinOfAvg rise	-	mm/day
MaxOfAvg rise	-	mm/day
AvgOfAvg rise	-	mm/day
MinOfAvg fall	-	mm/day
MaxOfAvg fall	-	mm/day
AvgOfAvg fall	-	mm/day
MinOfSeason_trend	-	metres
MaxOfSeason_trend	-	metres
AvgOfSeason_trend	-	metres

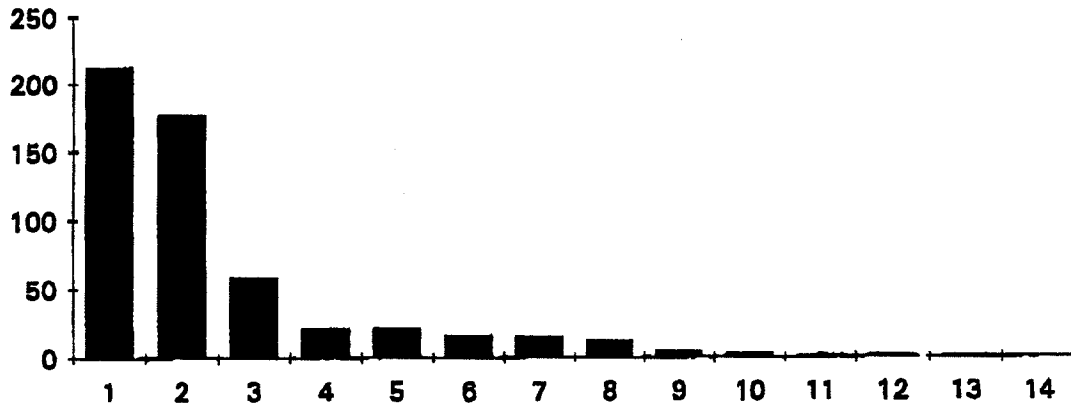
Stats - by HGU - 7 records (ascending order of HGU)

HGU	-	class
bores	-	number of bores
MinOfSeason_min	-	metres
MaxOfSeason_min	-	metres
AvgOfSeason_min	-	metres
MinOfSeason_max	-	metres
MaxOfSeason_max	-	metres
AvgOfSeason_max	-	metres
MinOfAvg rise	-	mm/day
MaxOfAvg rise	-	mm/day
AvgOfAvg rise	-	mm/day
MinOfAvg fall	-	mm/day
MaxOfAvg fall	-	mm/day
AvgOfAvg fall	-	mm/day
MinOfSeason_trend	-	metres
MaxOfSeason_trend	-	metres
AvgOfSeason_trend	-	metres

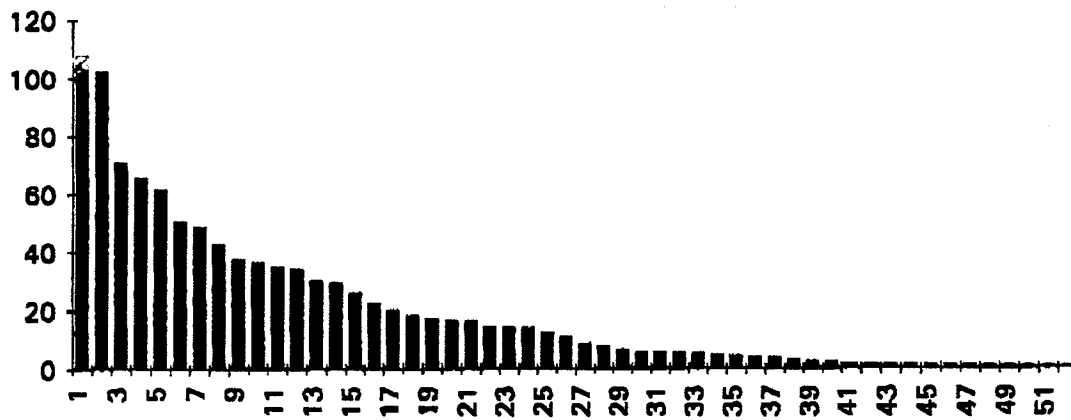
D. Hydraulic Conductivity

Hydraulic conductivity data from within the Loddon-Campaspe region was summarised by membership to geological type. The following results are extracted from the bore database (AL = alluvium, DL = deep leads, FR = fractured rock, VP = volcanics).

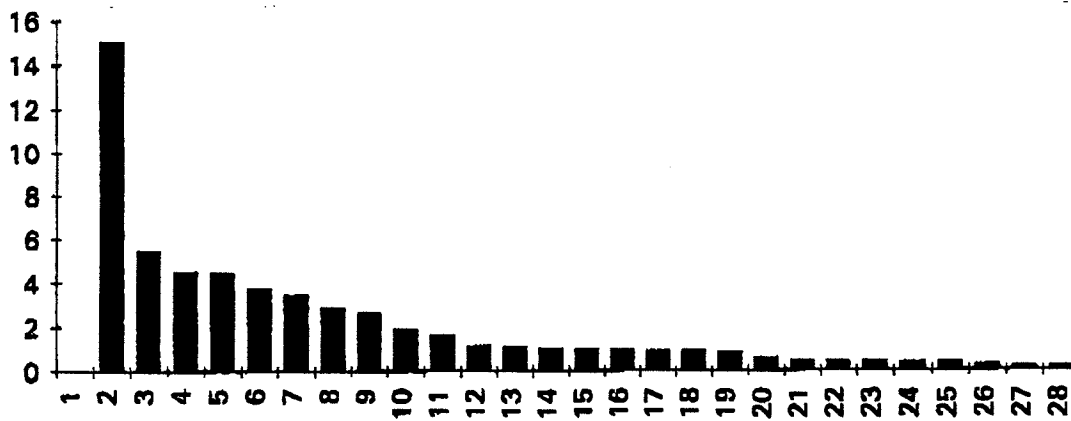
Histogram for AL Hydraulic Conductivity



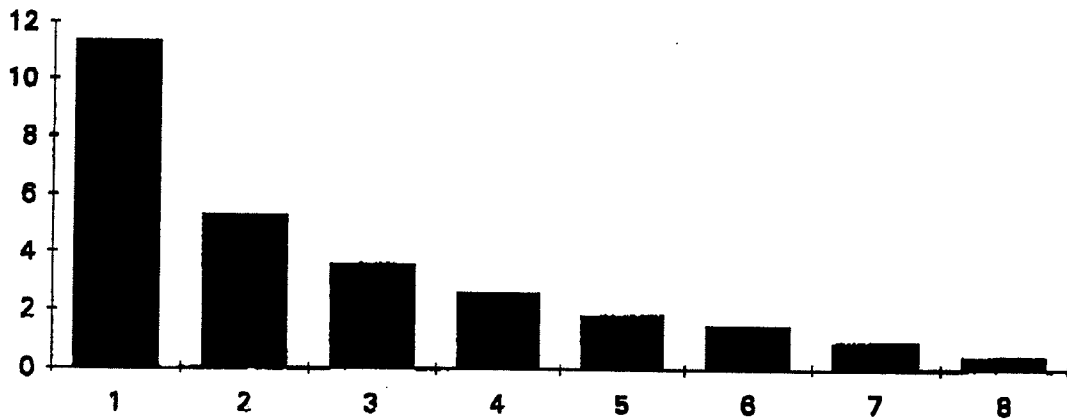
Histogram for DL Hydraulic Conductivity



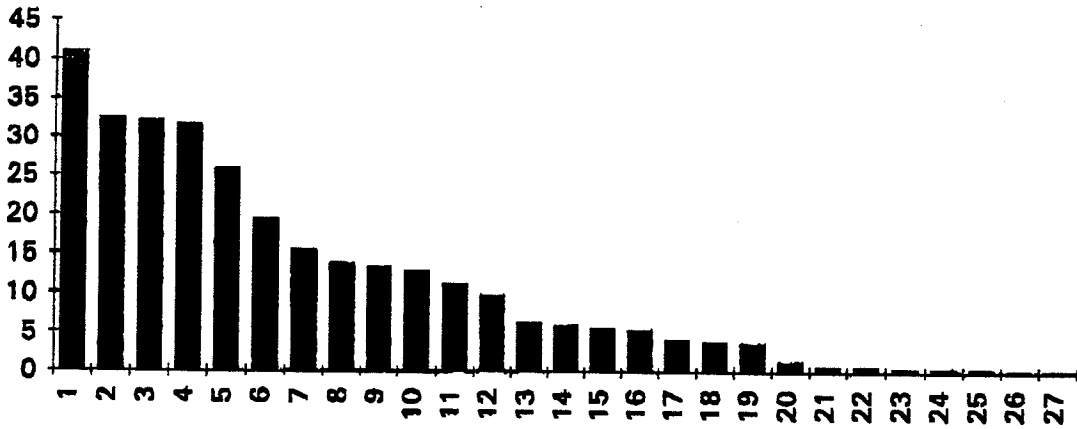
Histogram for FR Hydraulic Conductivity



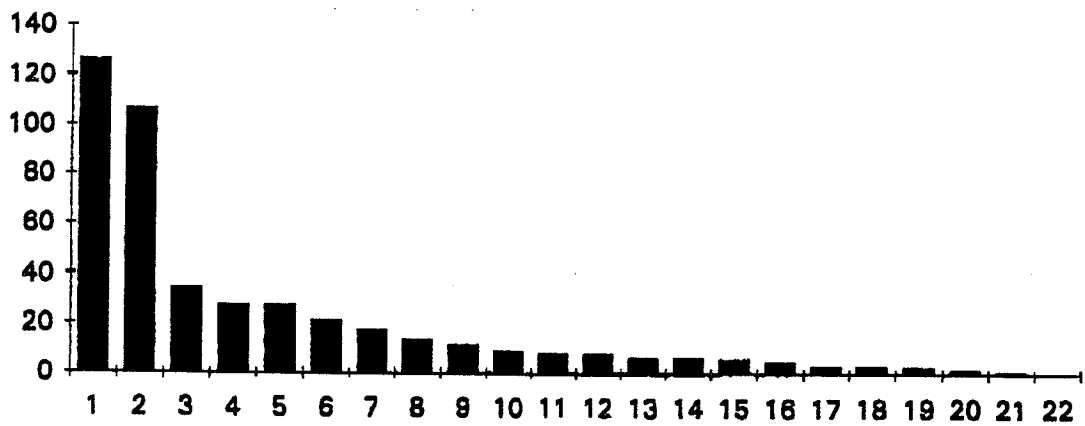
Histogram for GR Hydraulic Conductivity



Histogram for VP Hydraulic Conductivity



Histogram for SF Hydraulic Conductivity



III. Regression Analyses for Hydraulic Head Surface Estimation

Based on the above bore data and statistics, and a disaggregation of the catchment into HGU, geology and vegetation classes, regressions were developed between surface elevation and water levels toward the preparation of a hydraulic head surface. For each combination of geology, HGU and catchment class, and for each dataset of (x,y) where:

x = bore AHD elevation

y = bore 1991 minimum AHD water level

z = bore 1991 maximum AHD water level,

calculate regression equations

i. $y = ax + b$

ii. $y = ax^2 + bx + c$

iii. $z = ax + b$

iv. $z = ax^2 + bx + c$

On the following three pages, examples are offered for a series of water level relationships for the Loddon and Campaspe catchments in their entirety, and for arbitrary examples from the union of a geological class and an HGU class, and the geological class across the entire Loddon catchment.

catchment

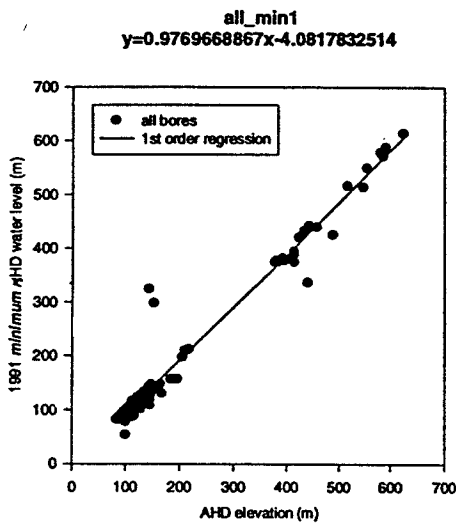
All bores in Loddon & Campaspe

1. [minimum 1991 AHD water level] by [AHD elevation]

648 data points

$$y = 0.9770x - 4.0818$$

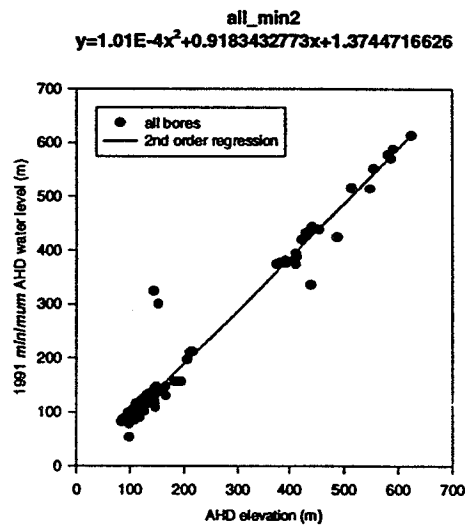
$$r^2 = 0.9763736012$$



648 data points

$$y = 1.01E-04x^2 + 0.9183x + 1.3745$$

$$r^2 = 0.9764808857$$

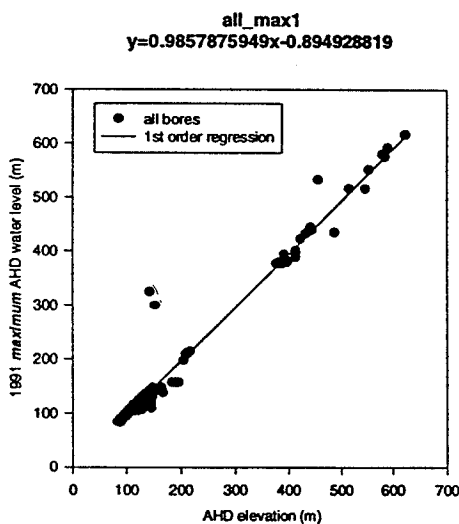


2. [maximum 1991 AHD water level] by [AHD elevation]

648 data points

$$y = 0.9858x - 0.8949$$

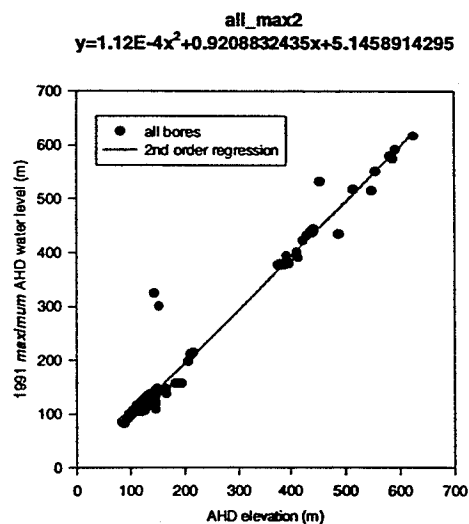
$$r^2 = 0.9808463914$$



648 data points

$$y = 1.12E-04x^2 + 0.9209x + 5.1459$$

$$r^2 = 0.9809761445$$



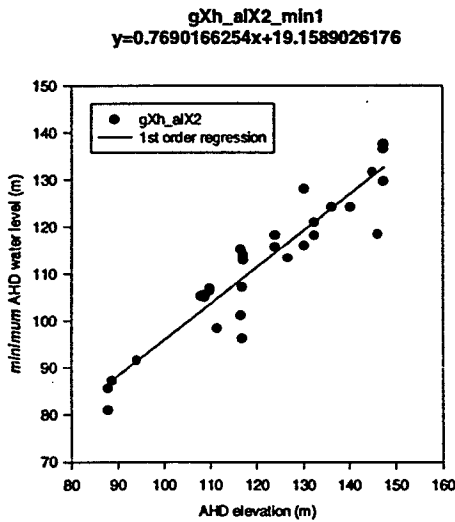
geology X HGU
Alluvial Deposits on 0.5° to 1.0° slopes

1. [minimum AHD water level] by [AHD elevation]

34 data points

$$y = 0.7690x + 19.1589$$

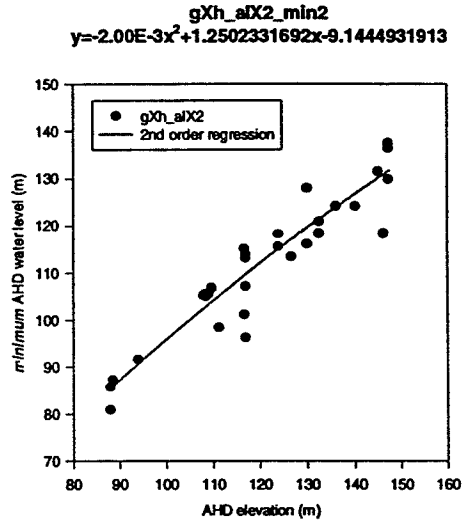
$$r^2 = 0.8791322847$$



34 data points

$$y = -2.00E-03x^2 + 1.2502x - 9.1445$$

$$r^2 = 0.8814176774$$

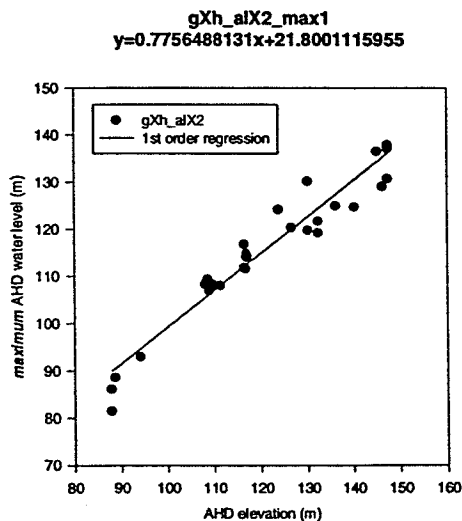


2. [maximum AHD water level] by [AHD elevation]

34 data points

$$y = 0.7756x + 21.8001$$

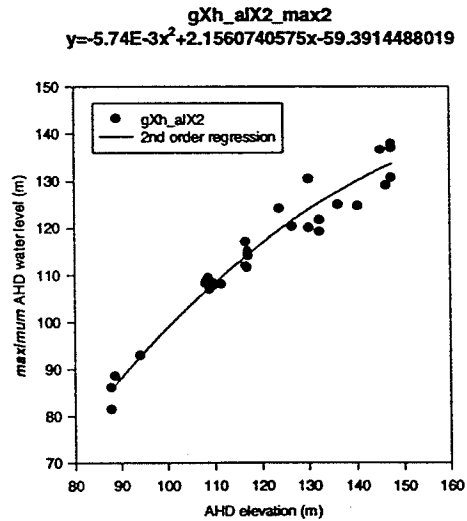
$$r^2 = 0.9299022404$$



34 data points

$$y = -5.7442E-03x^2 + 2.1561x - 59.3914$$

$$r^2 = 0.9494559779$$



geology X catchment
Sedimentary Formations in Loddon

1. [minimum 1991 AHD water level] by [AHD elevation]

28 data points

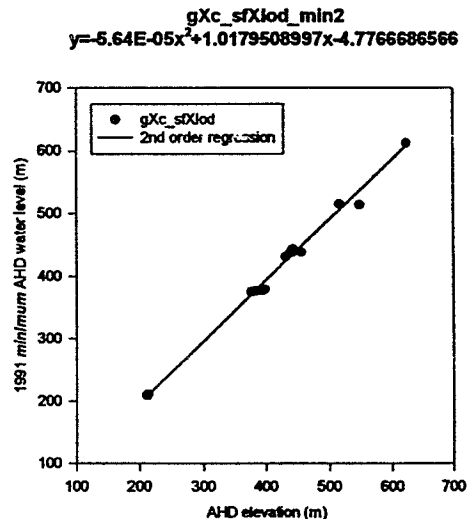
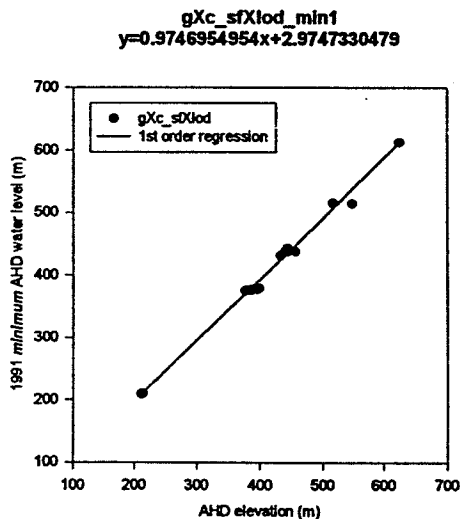
$$y = 0.9747x + 2.9747$$

$$r^2 = 0.99353344$$

28 data points

$$y = -5.64E-05x^2 + 1.0180x - 4.7767$$

$$r^2 = 0.993605864$$



2. [maximum 1991 AHD water level] by [AHD elevation]

28 data points

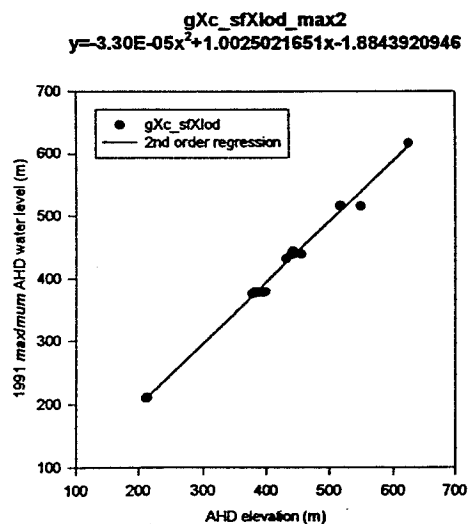
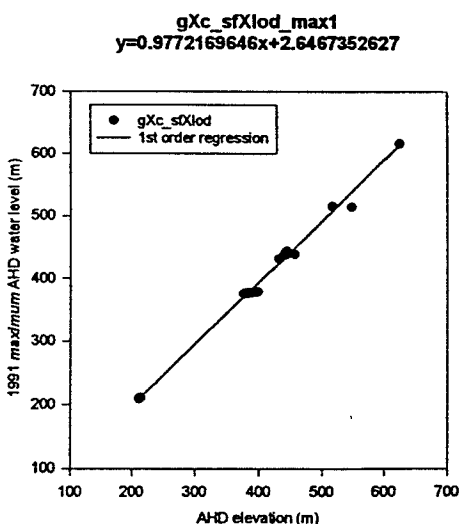
$$y = 0.9772x + 2.6467$$

$$r^2 = 0.993495843$$

28 data points

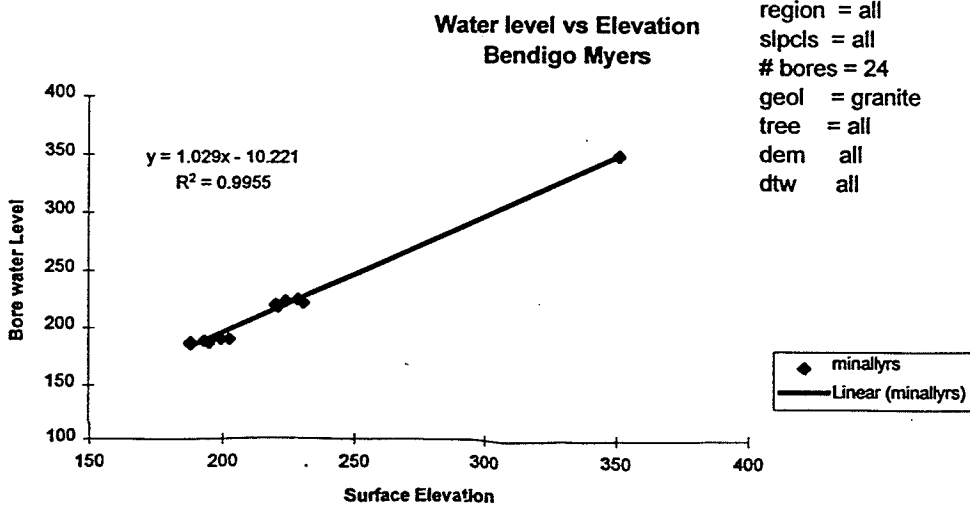
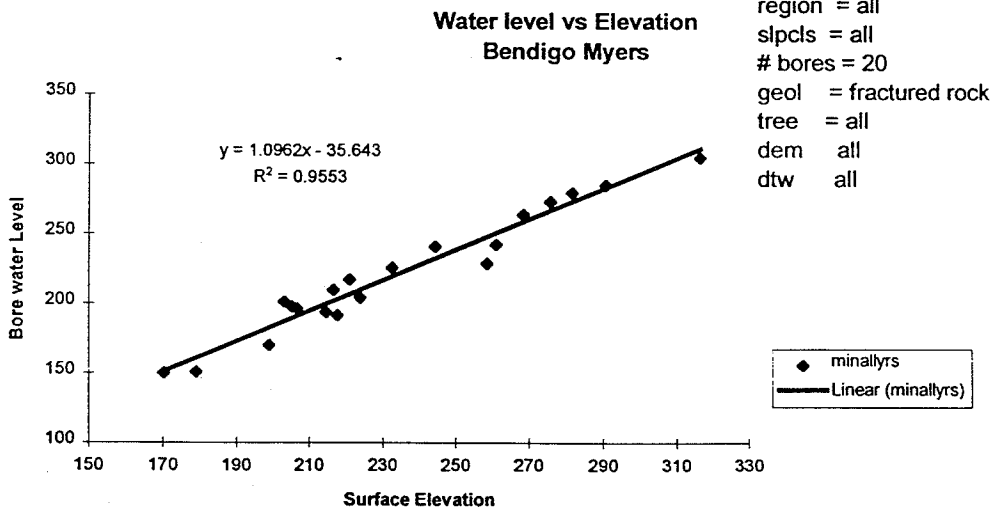
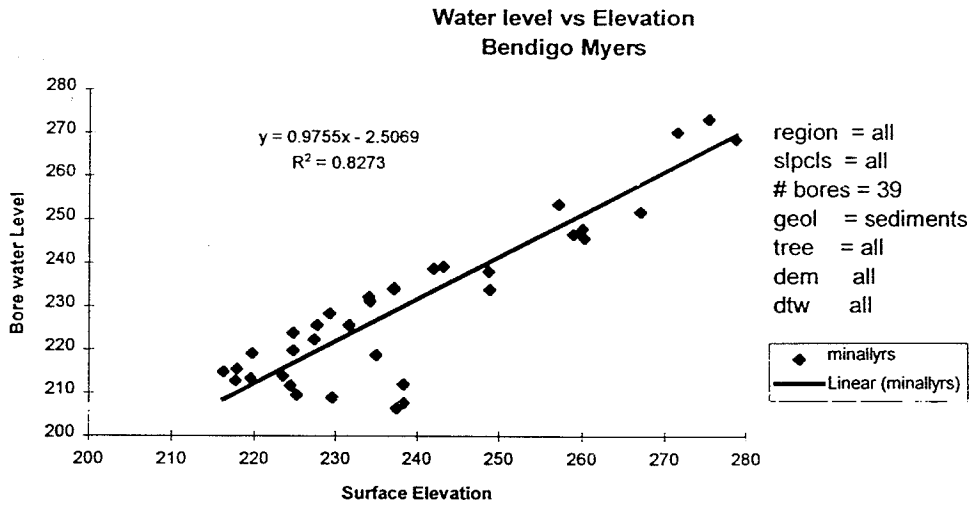
$$y = -3.30E-05x^2 + 1.0025x - 1.8844$$

$$r^2 = 0.993520462$$



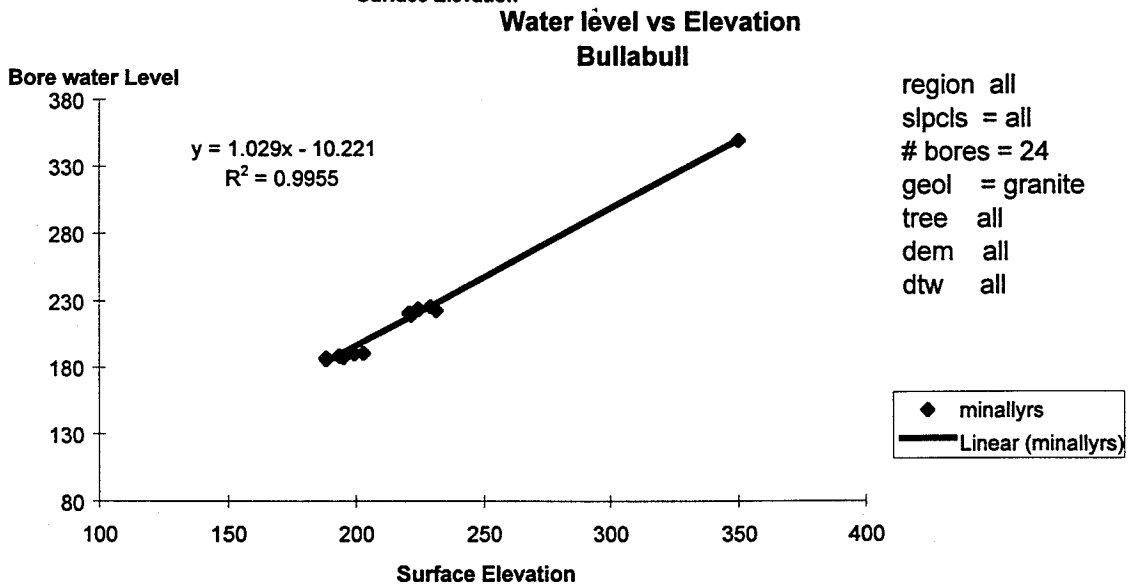
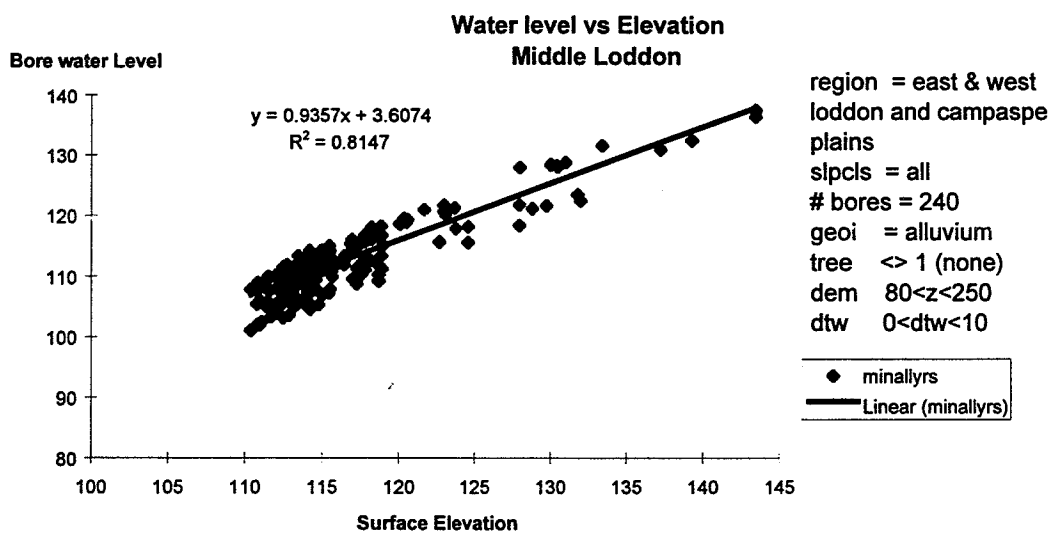
Bendigo Regressions

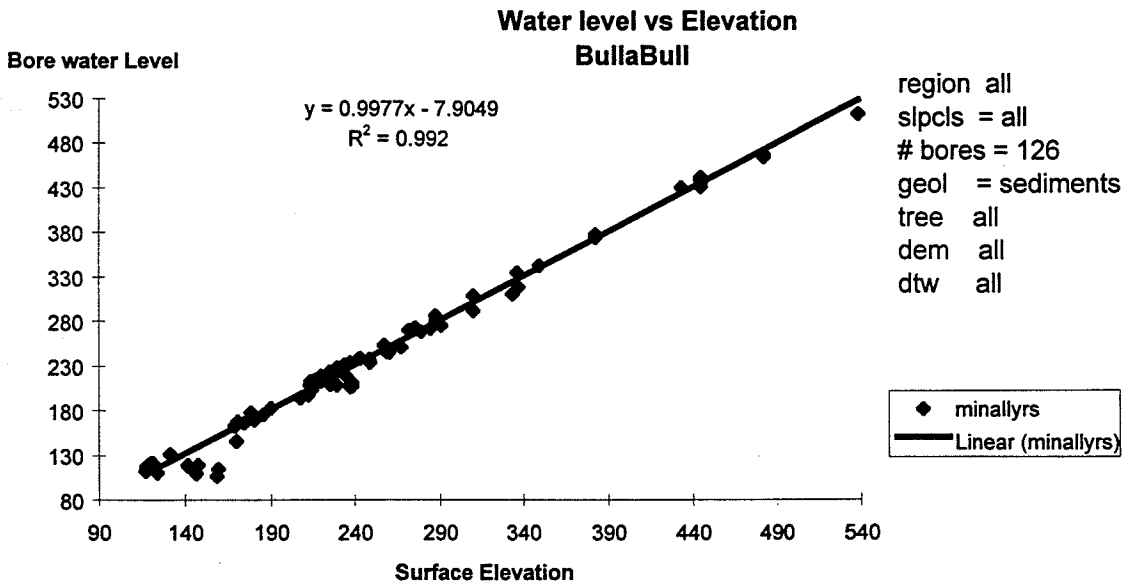
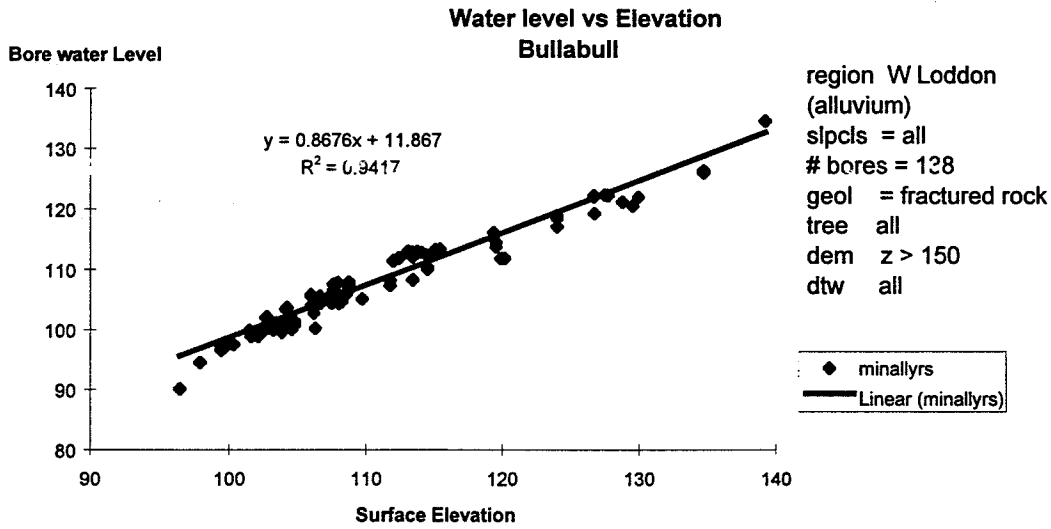
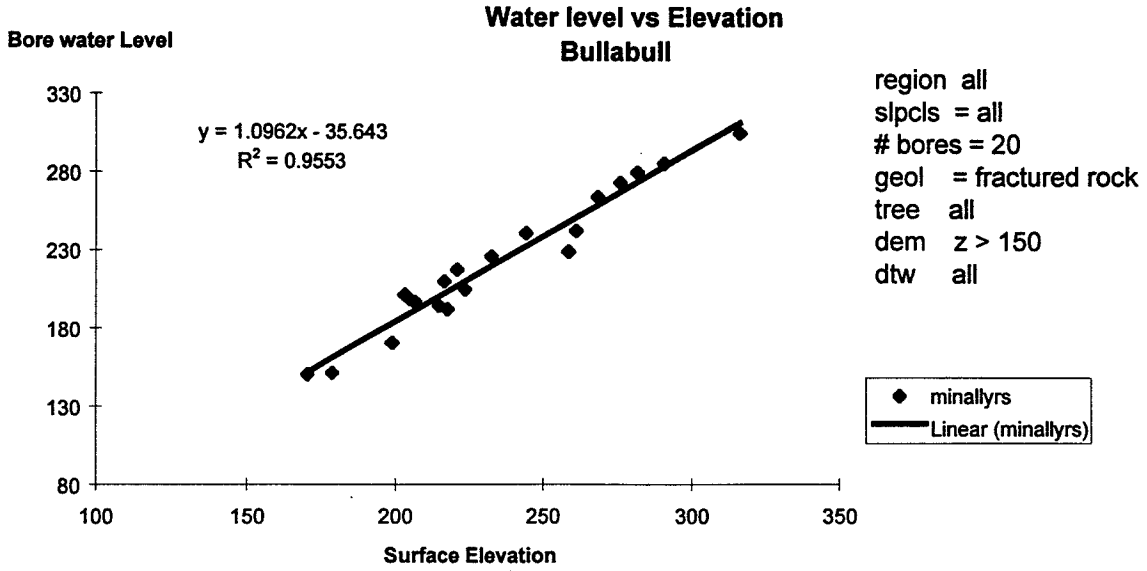
bore set	elevation min	elev-max	#bores	geology	tree class	dtw	slope class	a	b
all	215	280	39	sediments	all	all	all	.9755	-2.05
all	70	900	20	fractured rock	all	all	all	1.09	-35.6
all	70	900	24	granitic	all	all	all	1.02	-10.22

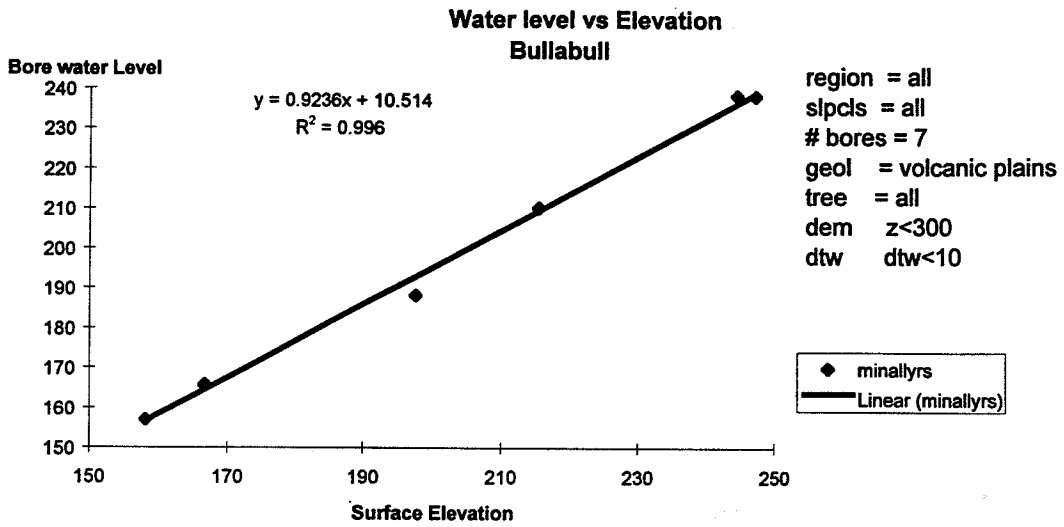


Bulla Bull Regressions

bore set	elevation min	elev-max	#bores	geology	tree class	dtw	slope class	a	b
East Loddon Campaspe Plains	80	250	260	alluvium	all	all	all	.9903	-2.8
all	70	900	240	sediments	all	all	all	0.97	-7.9
all	130	400	24	granites	all	all	all	1.03	-10.2
all	70	300	7	volcanics	all	dtw<10	all	0.92	+10.5
all	70	150	20	fractured rock	all	all	all	1.09	-35.6
all	150	900	20	fractured rock	all	all	all	.865	+11.87







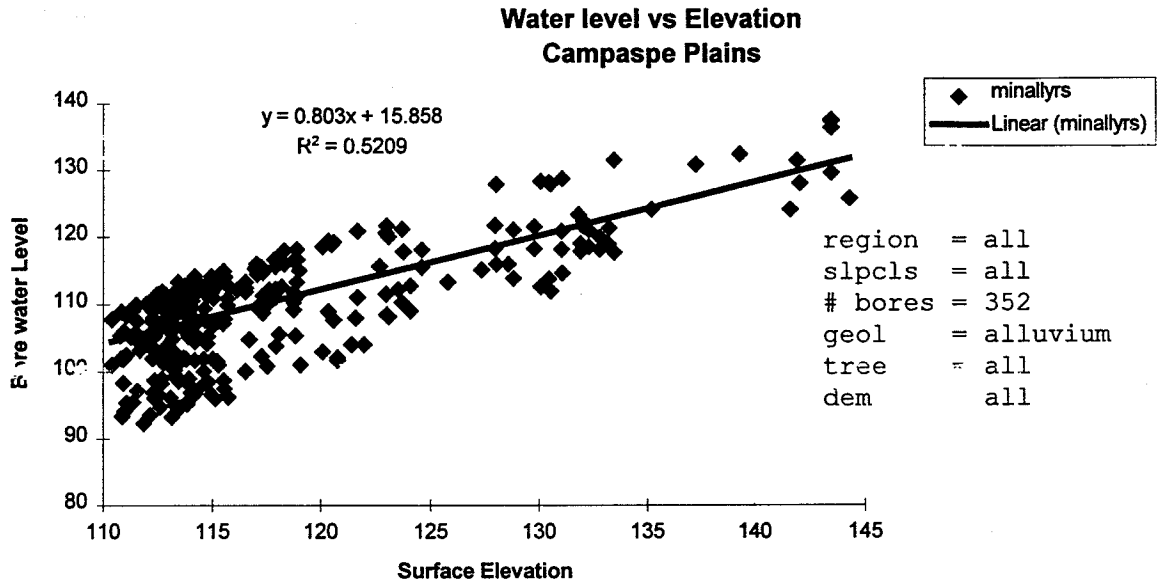
Campaspe Plains Regressions

Summary of the methods and relationships used to prepare the watertables for the regions and the subcatchments of the Loddon -Campaspe.

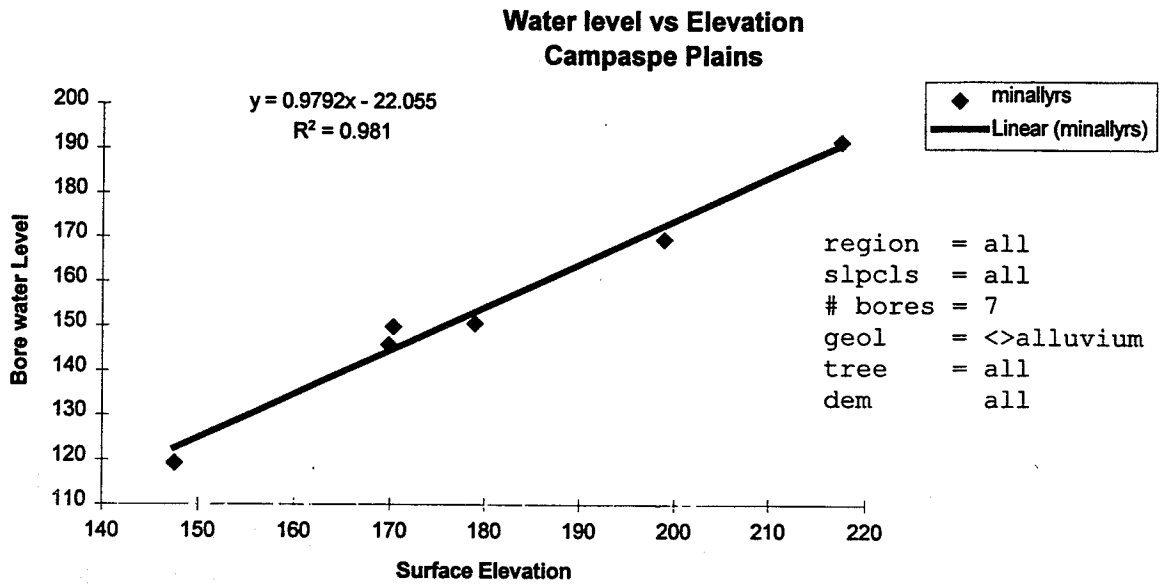
Method: Geology and Elevation Ranges

Subcatchment Groundwater relationships

Catchment	elevation min	elev-max	#bores	geology	tree class	slope class	a	b
Campaspe Plains	-	-	352	alluvium	all	all	0.8	+16

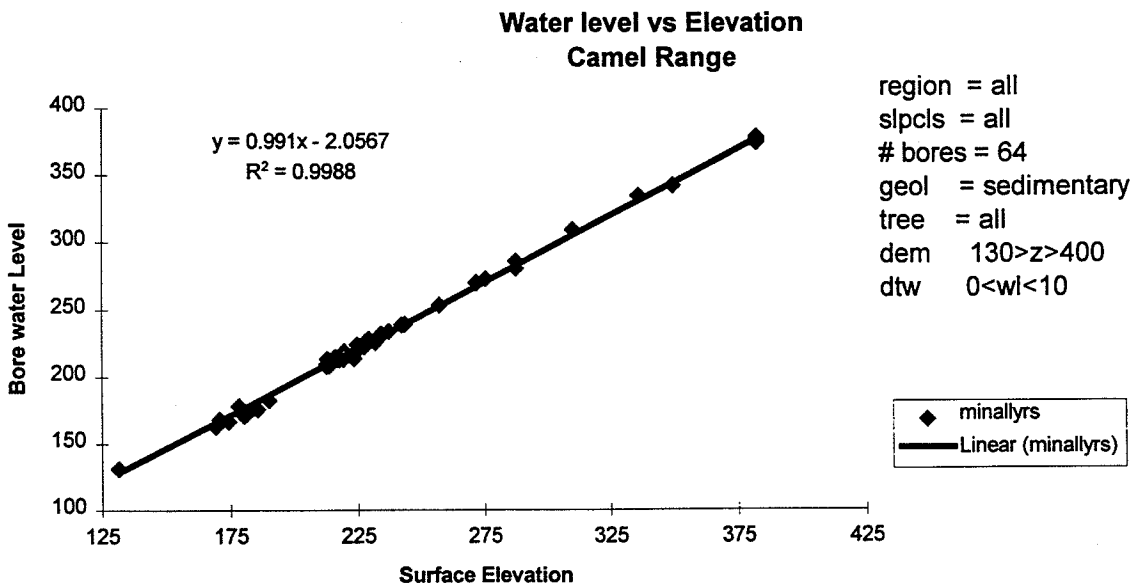
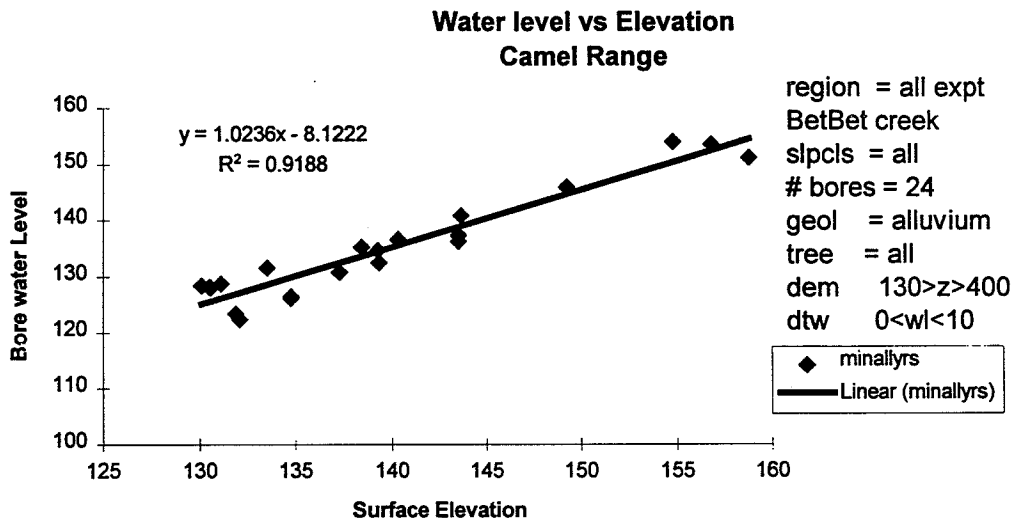


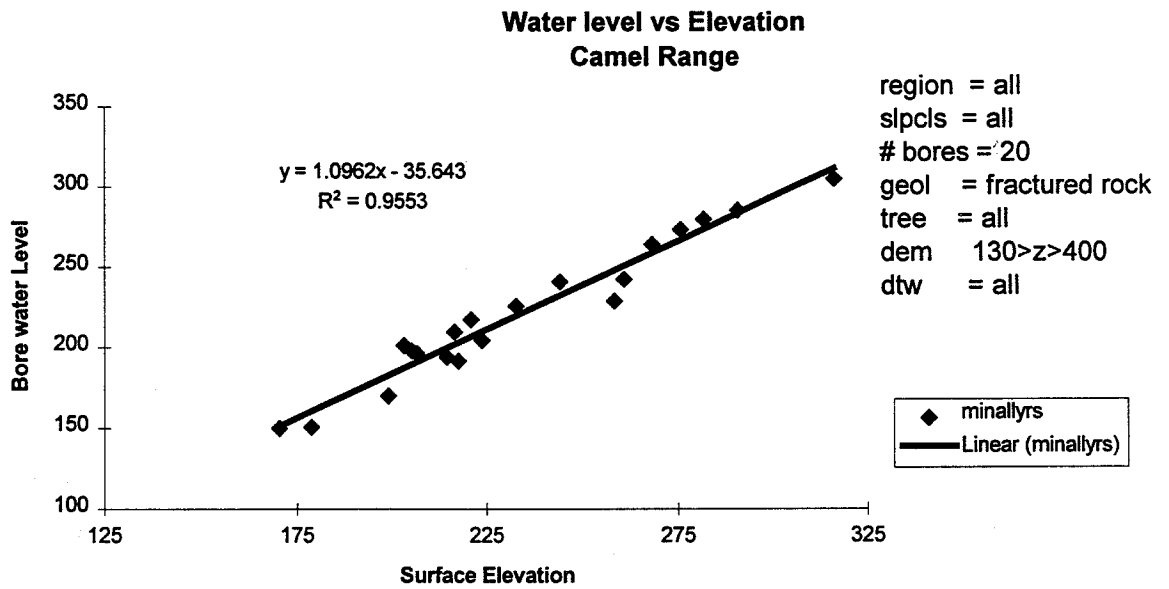
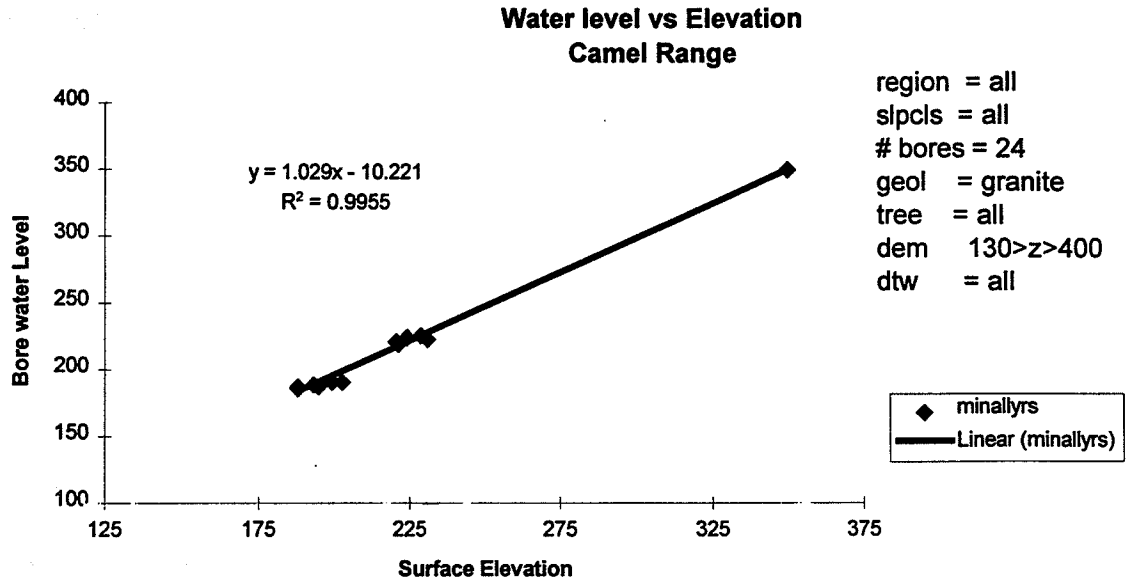
Catchment	elevation min	elev-max	#bores	geology	tree class	slope class	a	b
Campaspe Plains	-	-	352	alluvium	all	all	0.8	+16



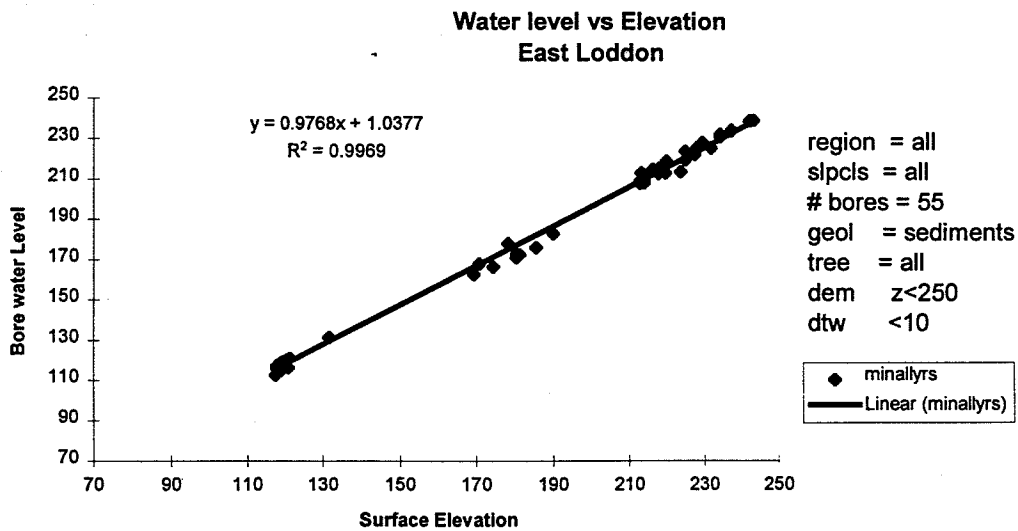
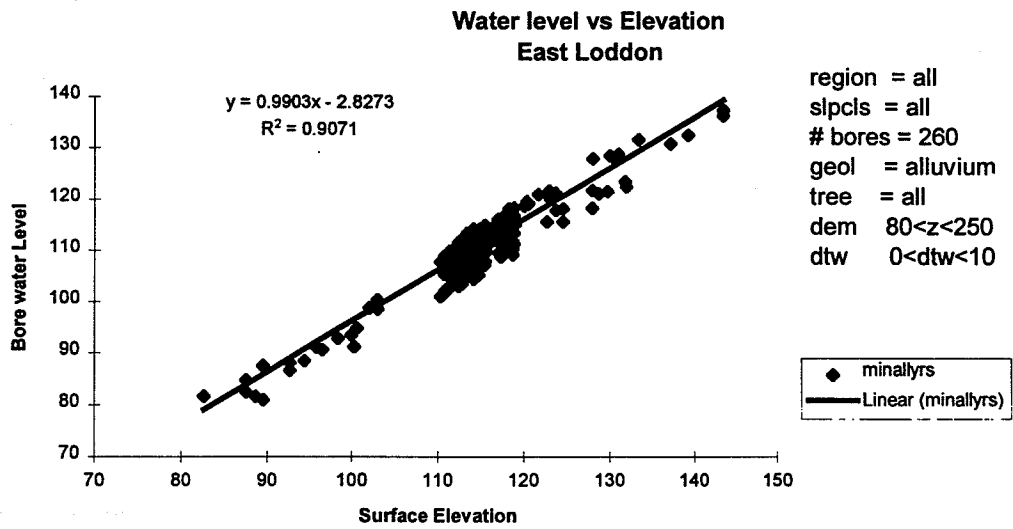
Camel Range Regressions

bore set	elevation min	elev-max	#bores	geology	tree class	dtw	slope class	a	b
all but Bet Bet	130	400	224	alluvium	all	<10	all	1.02	-8.12
	130	400	64	sediments	all	<10	all	.991	2.05
	130	400	24	granite	all	all	all	1.03	-10.2
	130	400	24	fractured rock	all	all	all	1.09	-35.6

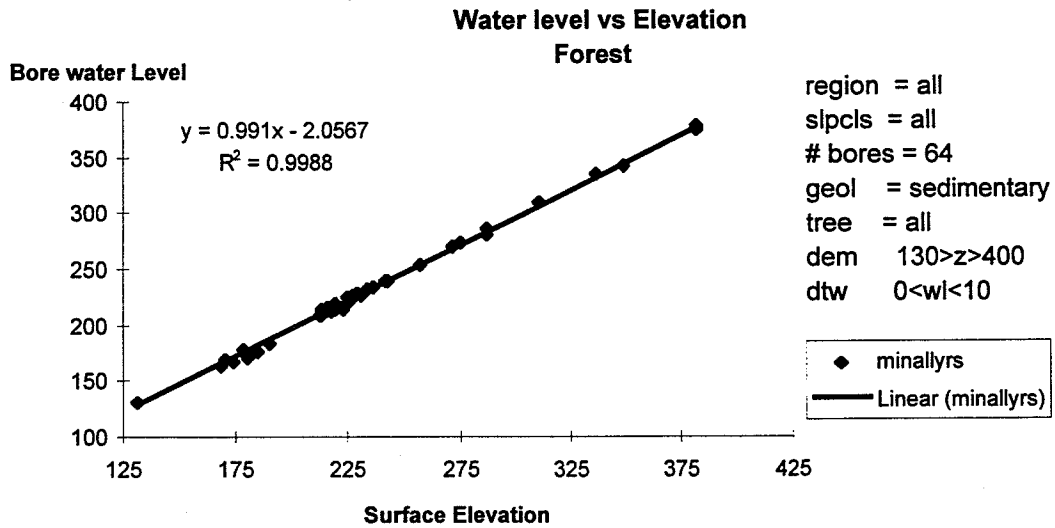
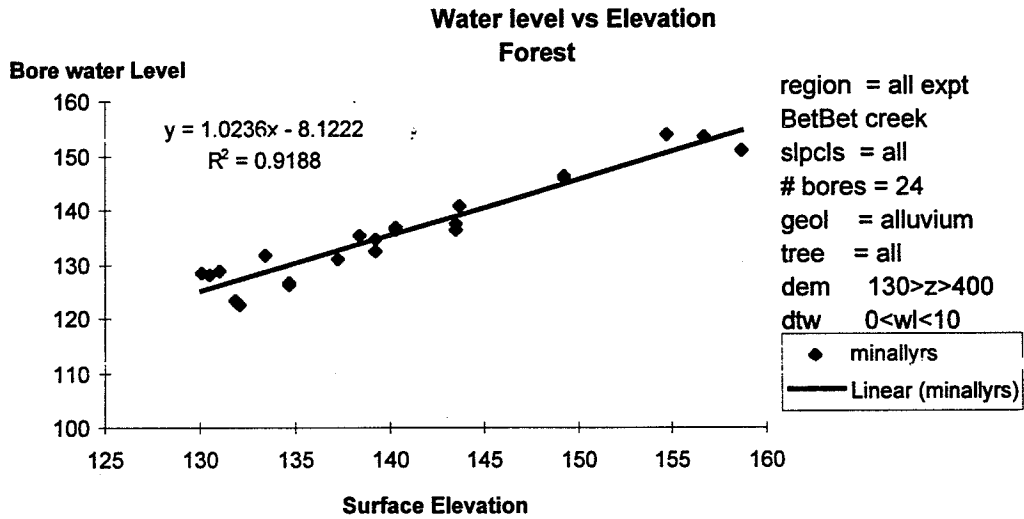


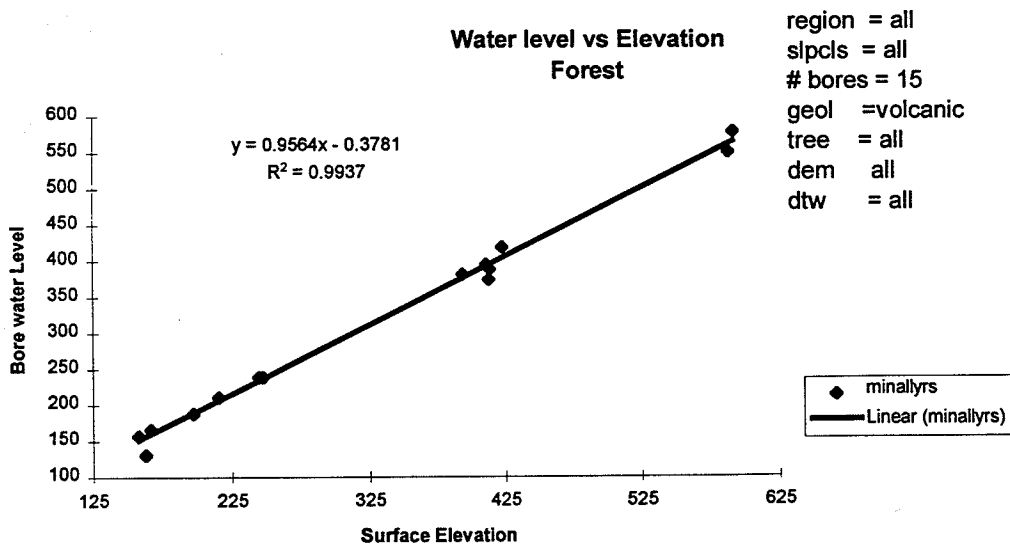
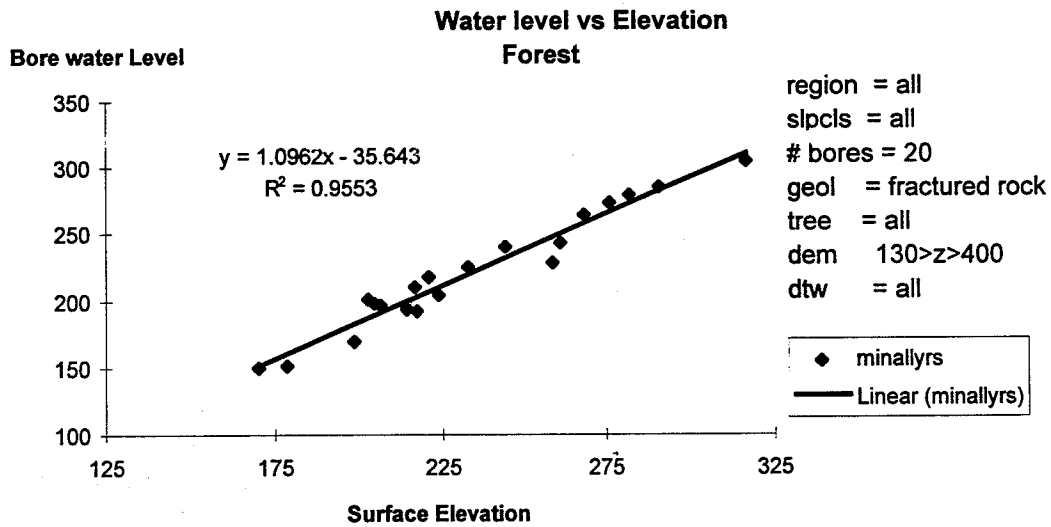
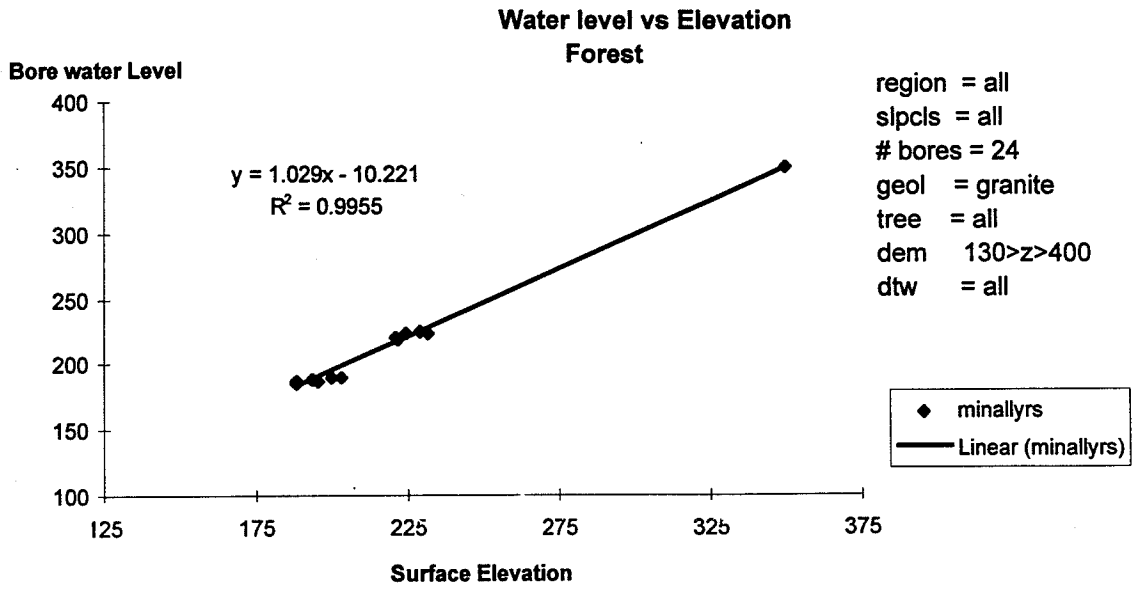


bore set	elevation min	elev-max	#bores	geology	tree class	dtw	slope class	a	b
East Loddon Campaspe Plains	80	250	260	alluvium	all	all	all	.9903	-2.8
all	70	250	55	sediments	all	all	all	0.97	+1.03



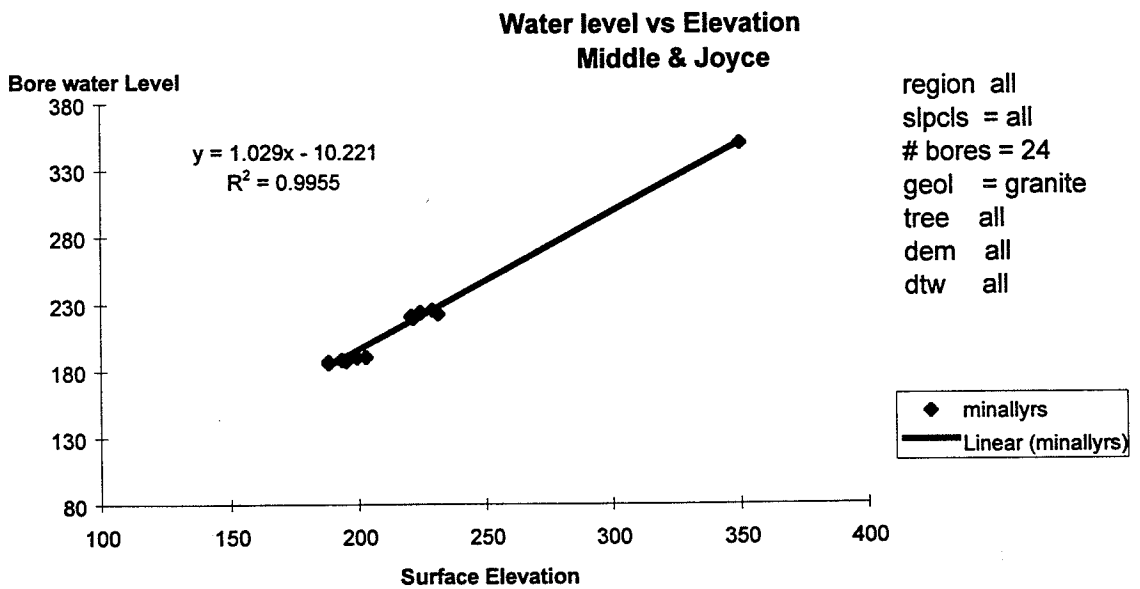
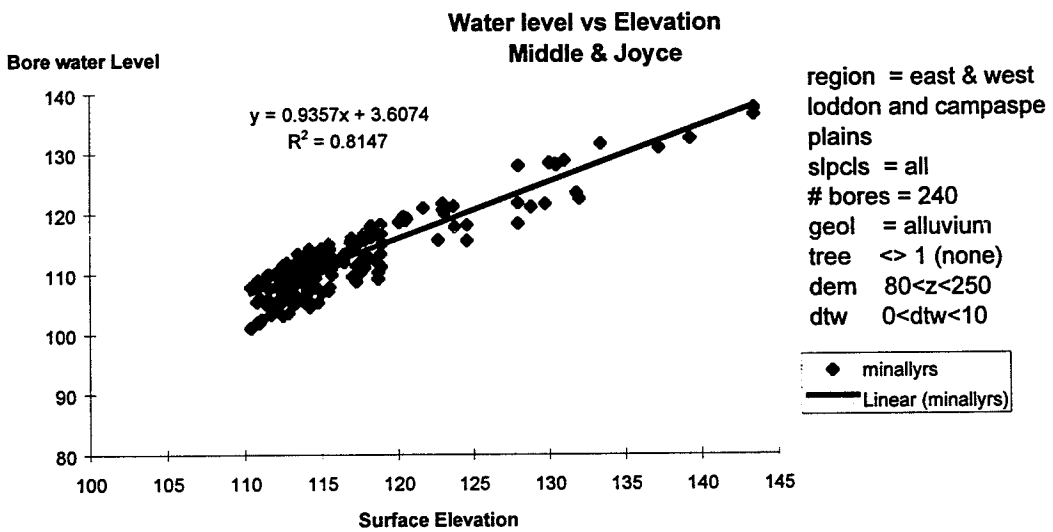
bore set	elevation min	elev-max	#bores	geology	tree class	dtw	slope class	a	b
all but Bet Bet	130	400	224	alluvium	all	<10	all	1.02	-8.12
	130	400	64	sediments	all	<10	all	.991	2.05
	130	400	24	granite	all	all	all	1.03	-10.2
	130	400	24	fractured rock	all	all	all	1.09	-35.6

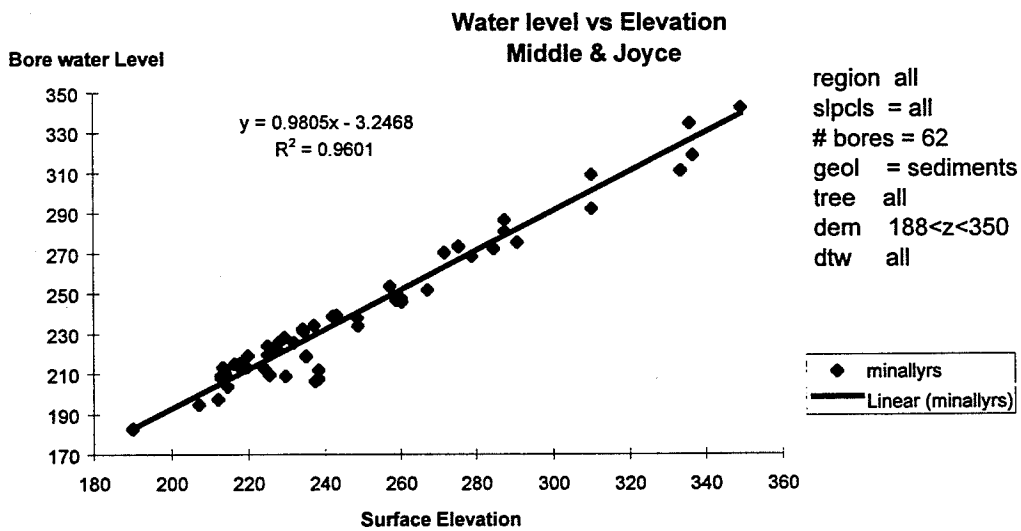
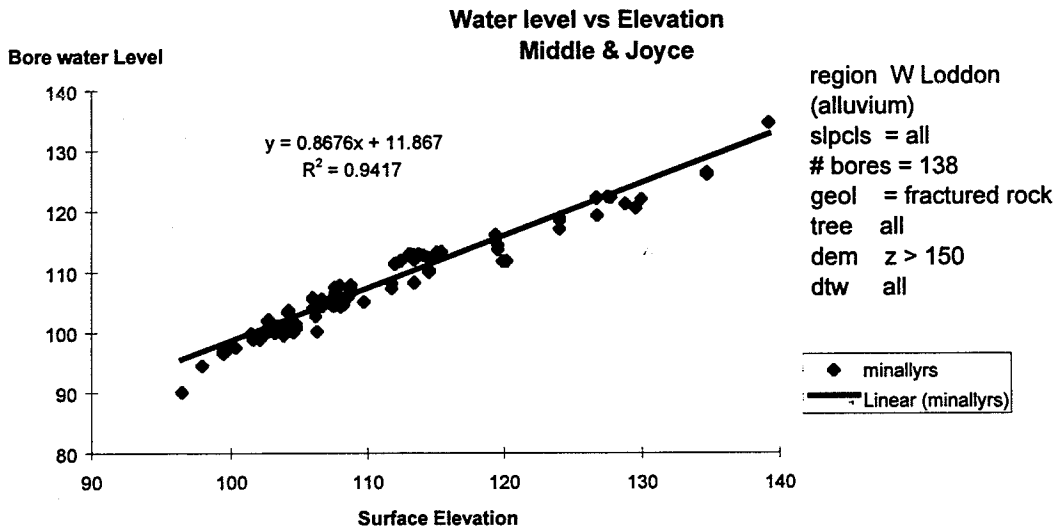
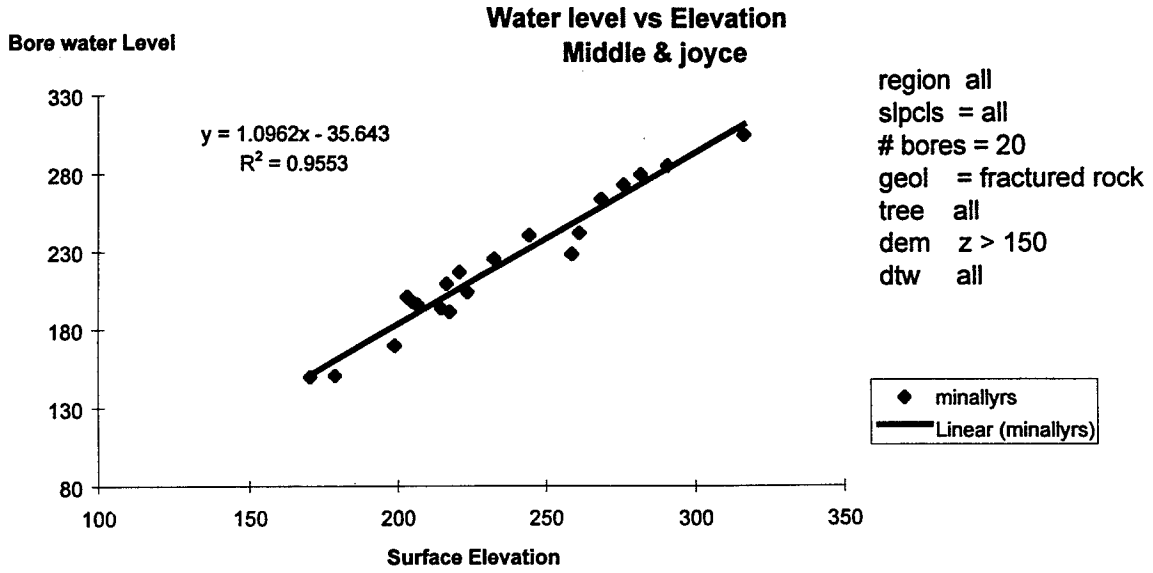


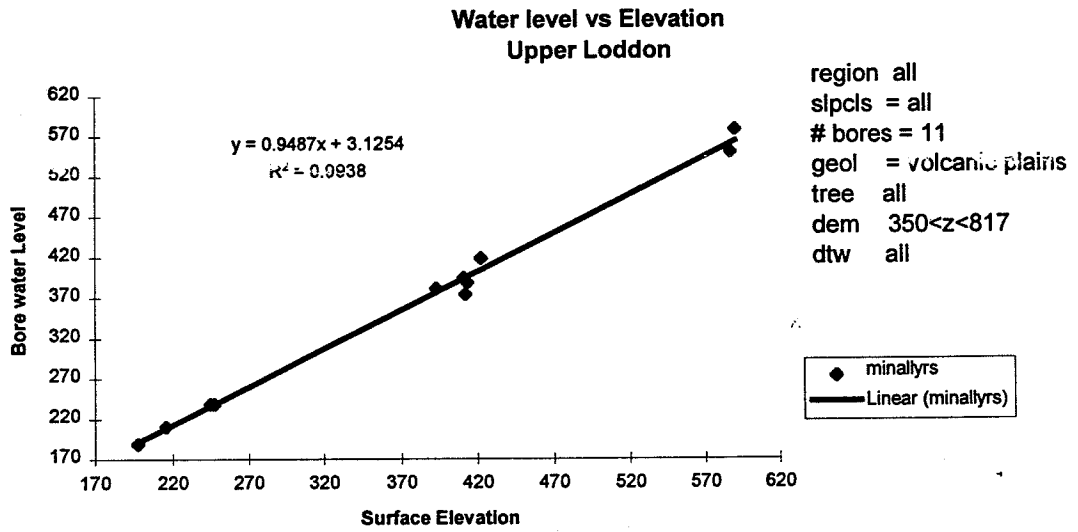
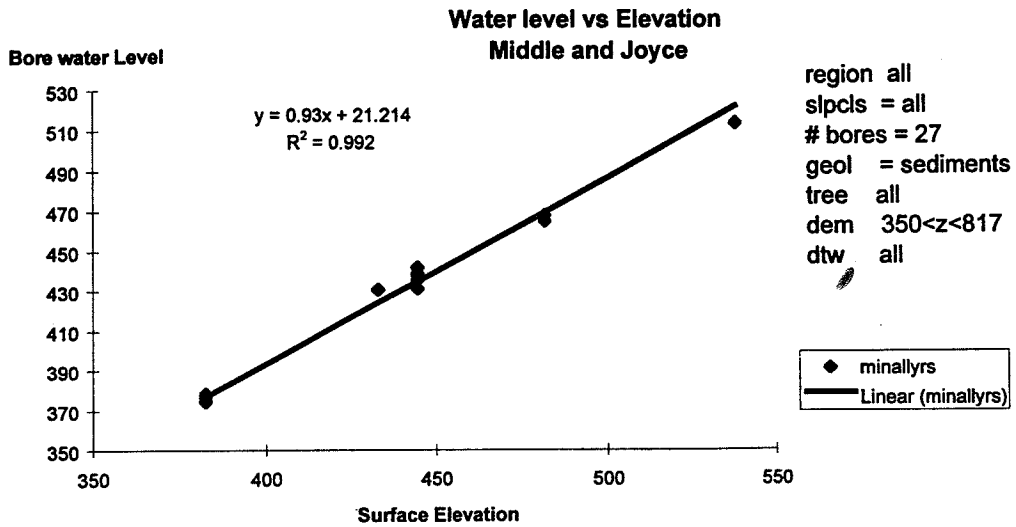


Middle & Joyce Regressions

bore set	elevation min	elev-max	#bores	geology	tree class	dtw	slope class	a	b
East Loddon	80	250	260	alluvium	all	all	all	.9903	-2.8
Campaspe Plains									
all	70	900	240	sediments	all	all	all	0.97	-7.9
all	130	400	24	granites	all	all	all	1.03	-10.2
all	70	300	7	volcanics	all	dtw<10	all	0.92	+10.5
all	70	150	20	fractured rock	all	all	all	1.09	-35.6
all	150	900	20	fractured rock	all	all	all	.865	+11.87

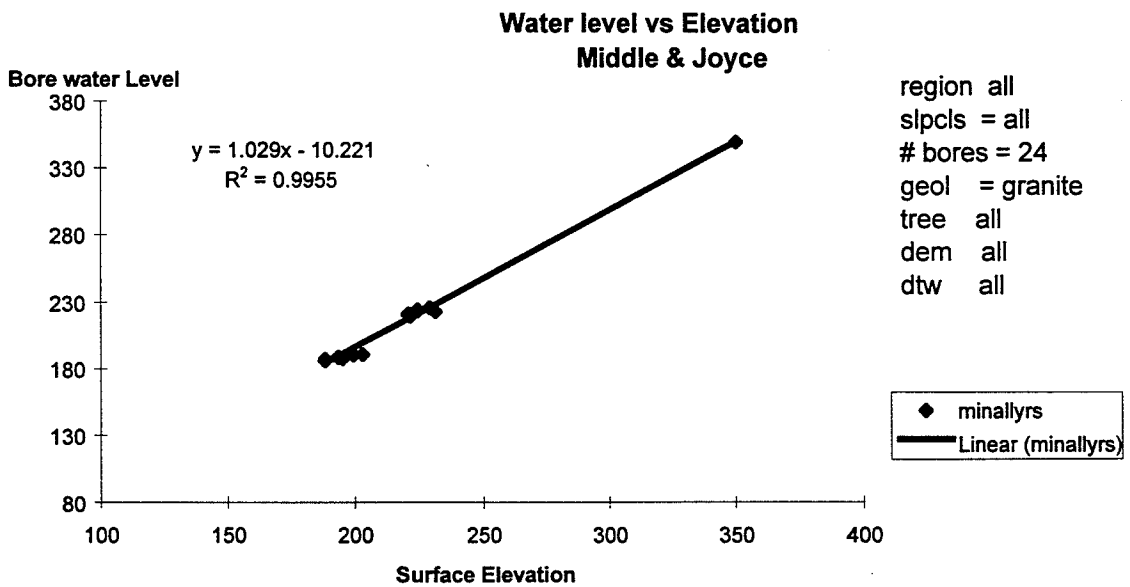
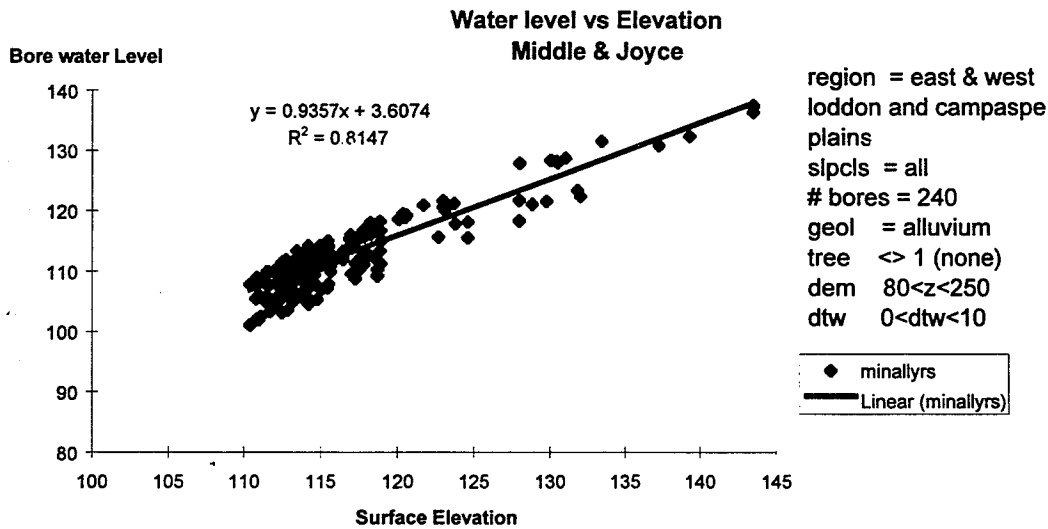


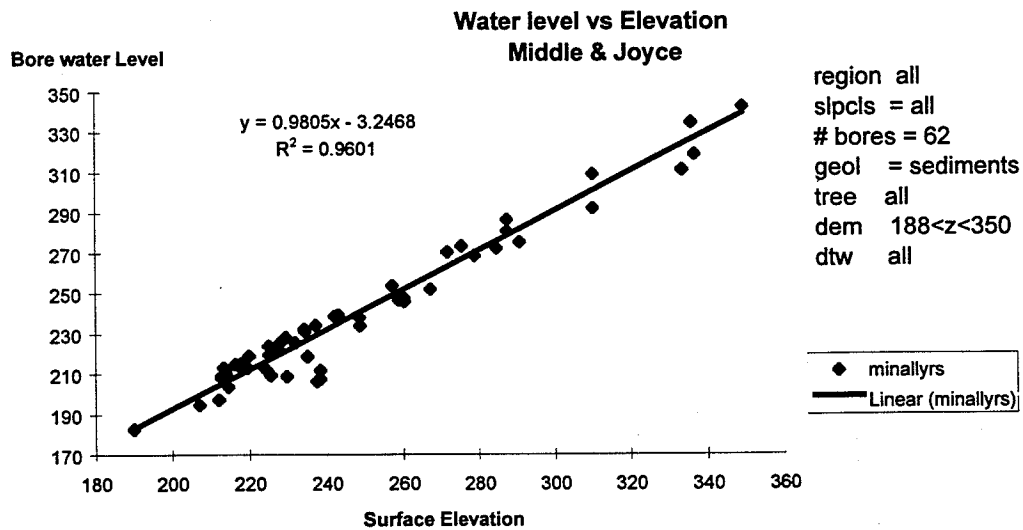
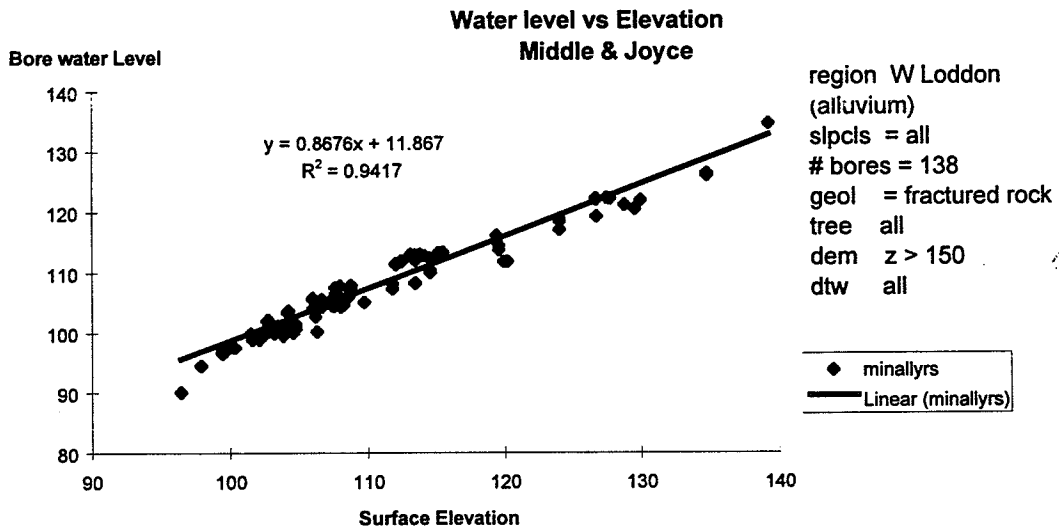
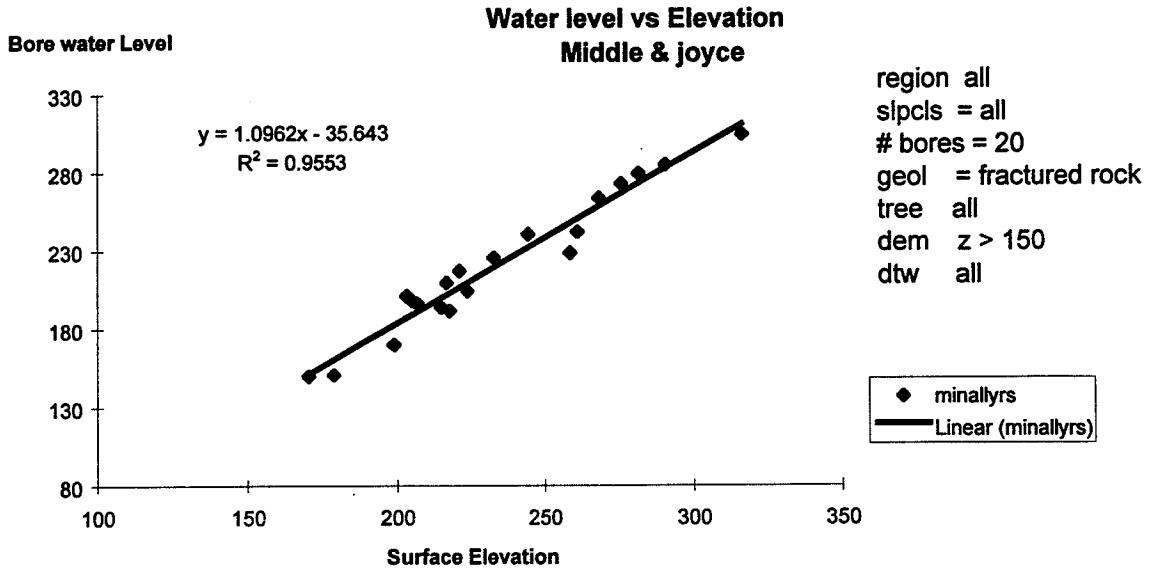


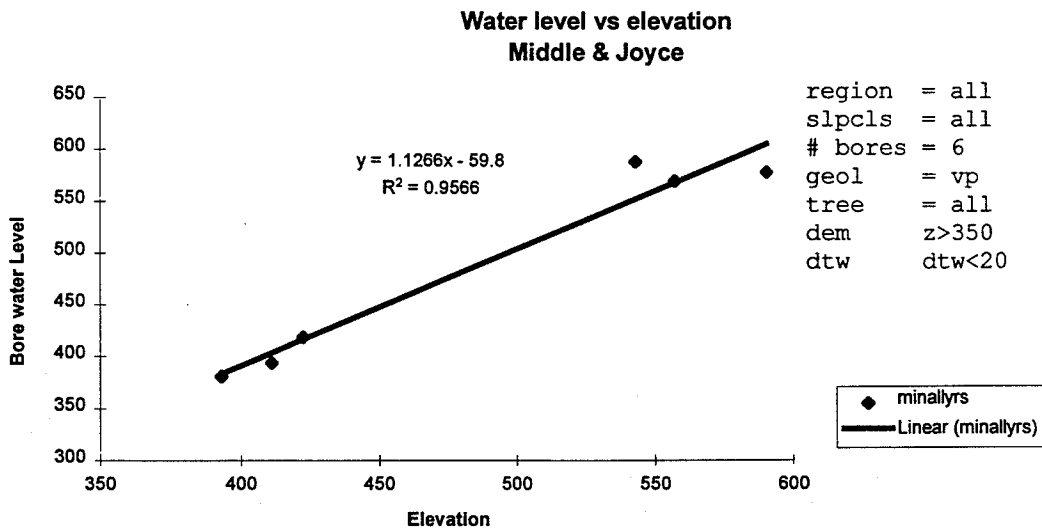
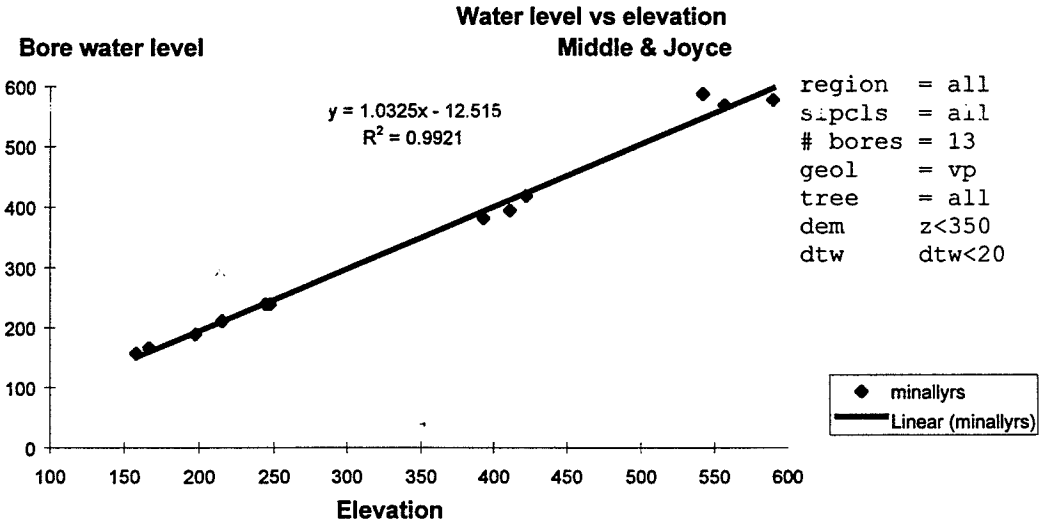
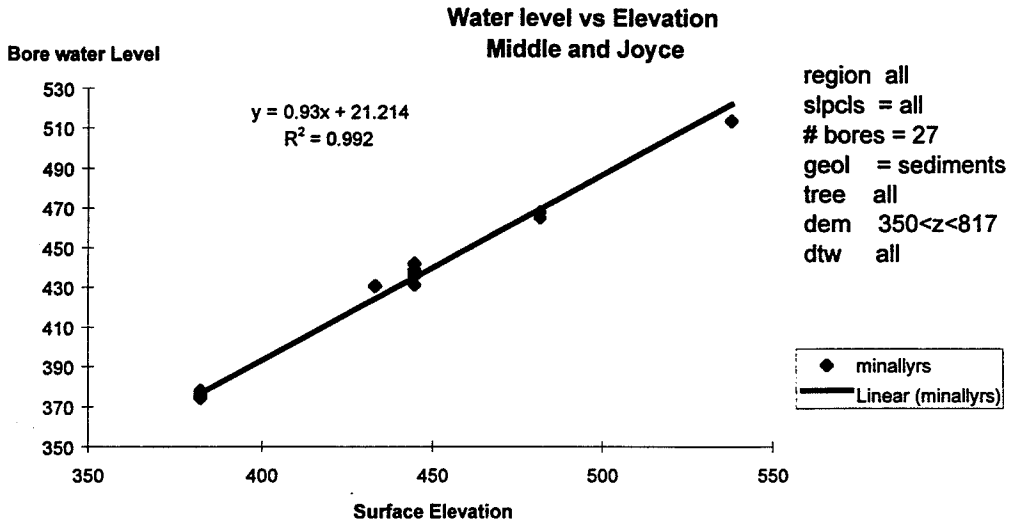


Middle & Joyce Regressions

bore set	elevation min	elevation max	#bores	geology	tree class	dtw	slope class	a	b
East Loddon Campaspe Plains	80	250	260	alluvium	all	all	all	.93	+3.6
all	130	400	24	granites	all	all	all	1.03	-10.2
all	70	150	20	fractured rock	all	all	all	1.09	-35.6
all	150	900	20	fractured rock	all	all	all	.865	+11.87
all	188	350	62	sediments	all	all	all	.98	-3.24
all	350	817	27	sediments	all	all	all	.93	+21
all	188	350	13	volcanic plains	all	all	all	1.03	-12.5
all	350	817	6	volcanic plains	all	all	all	1.12	-59

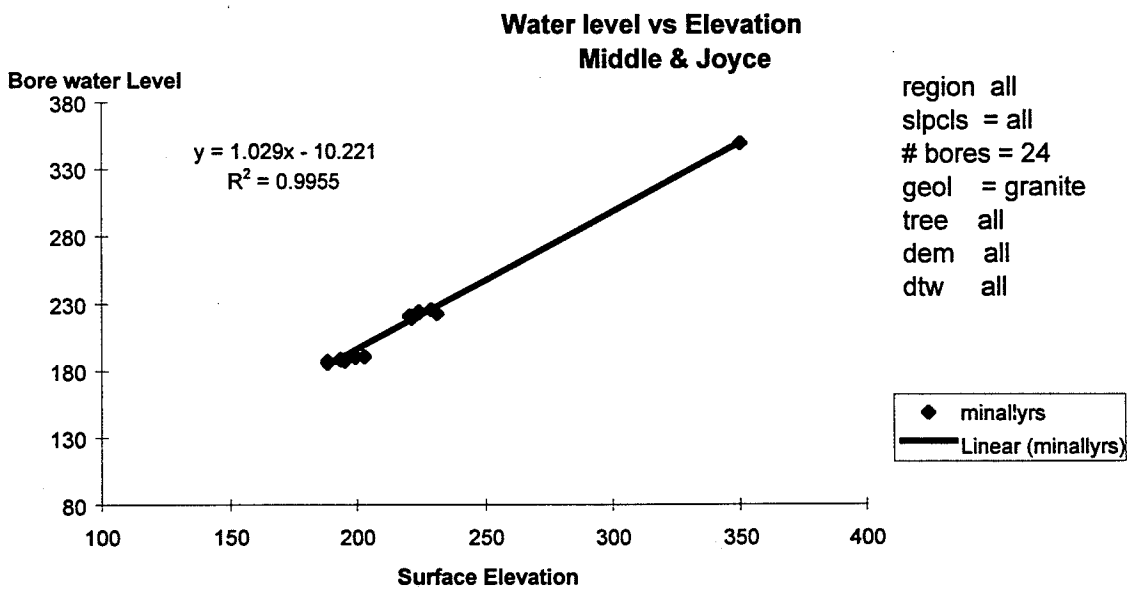
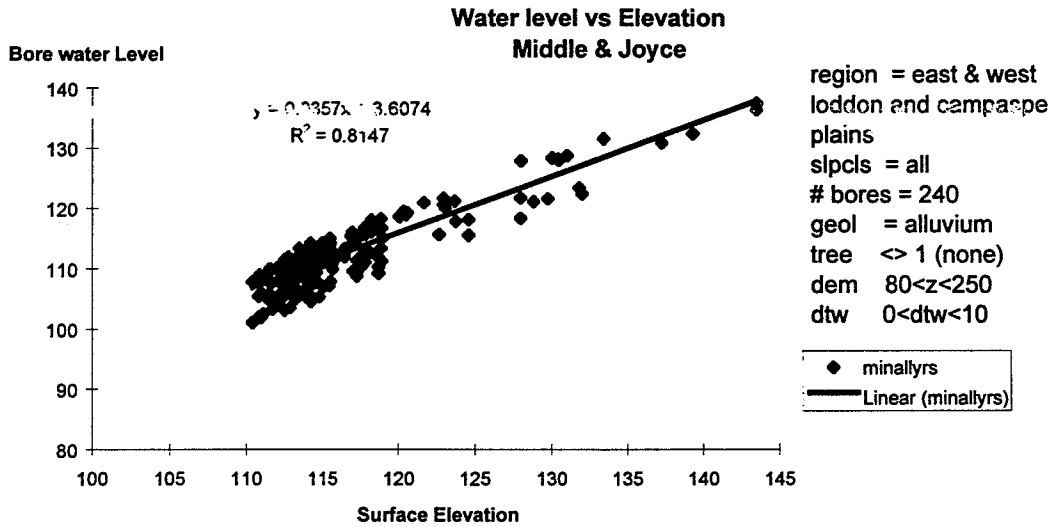


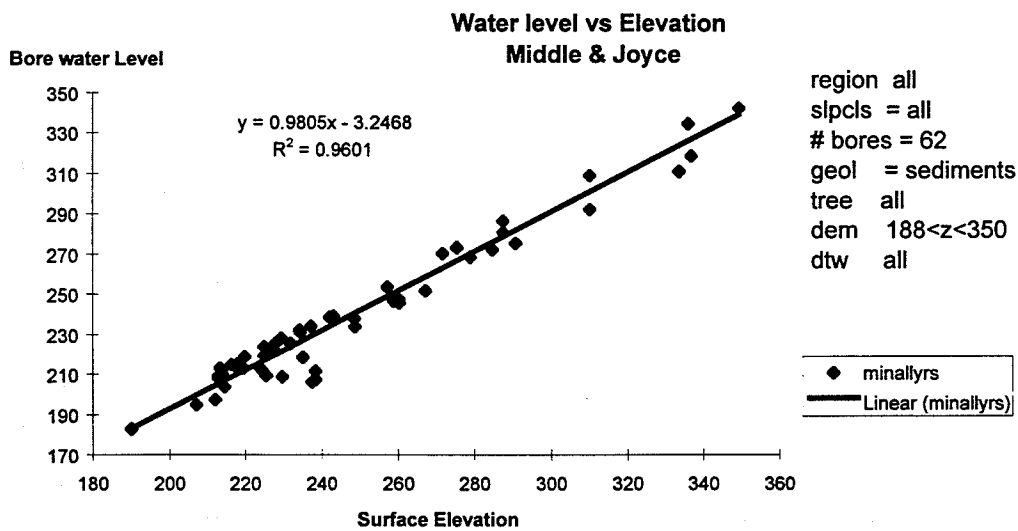
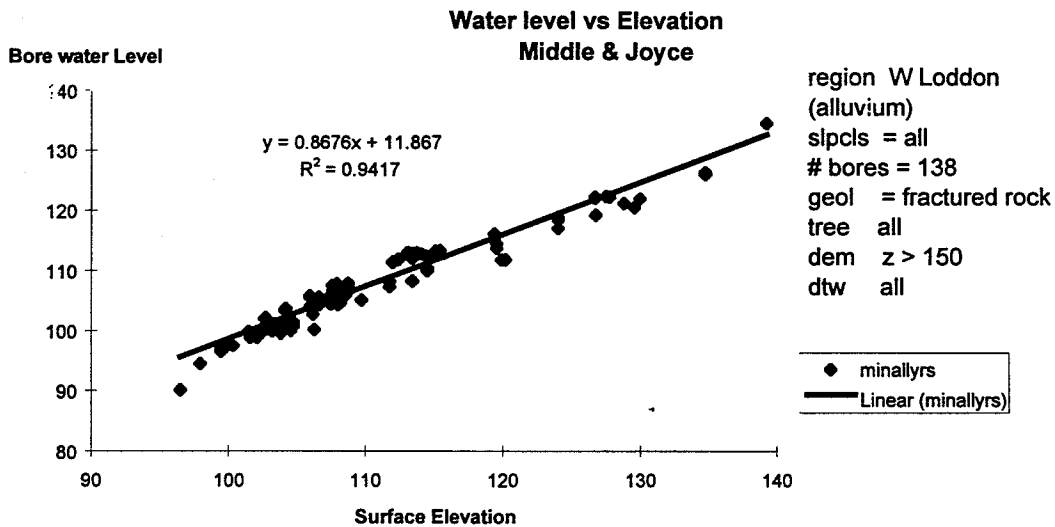
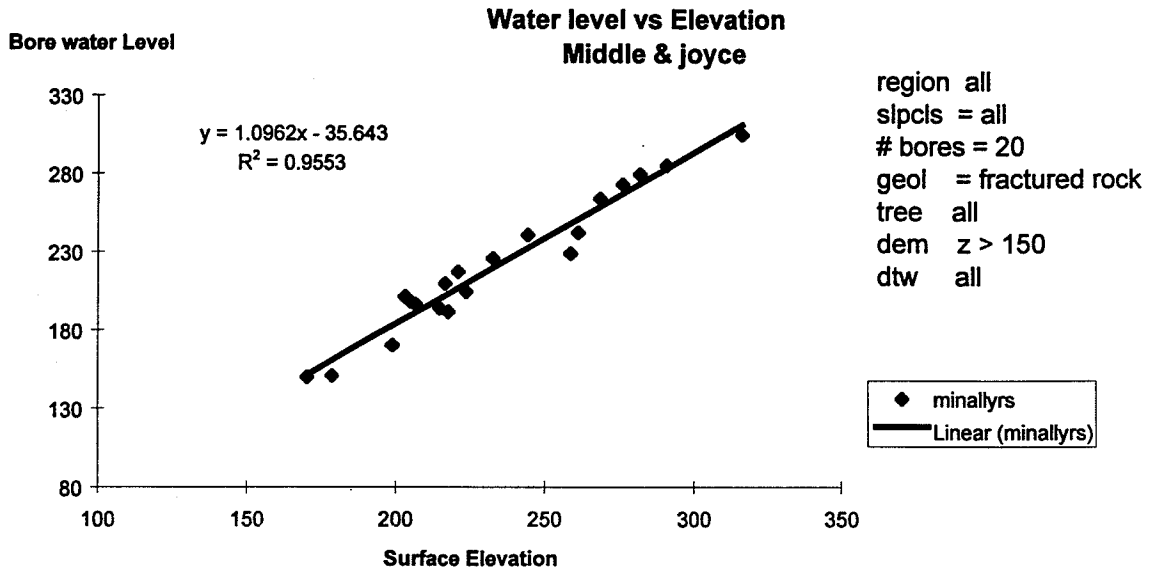


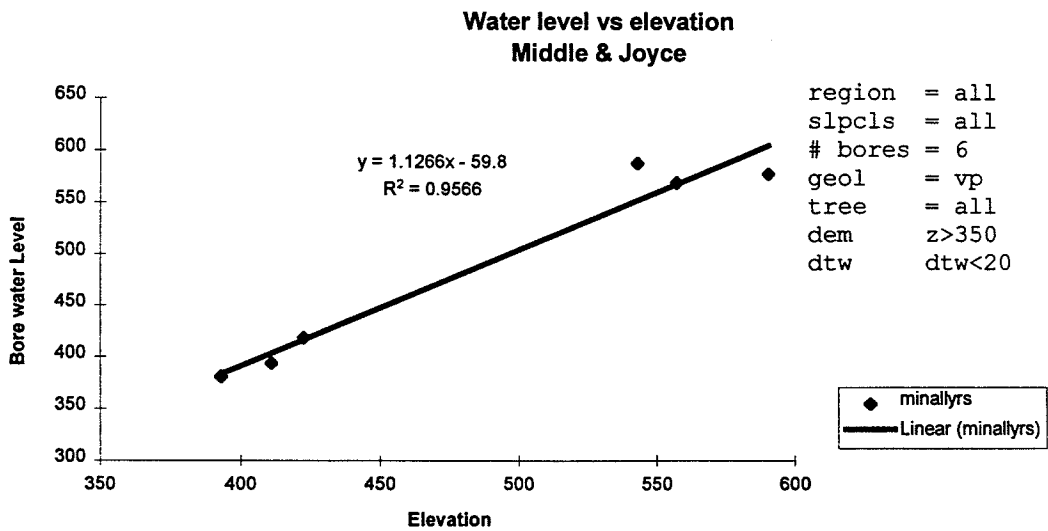
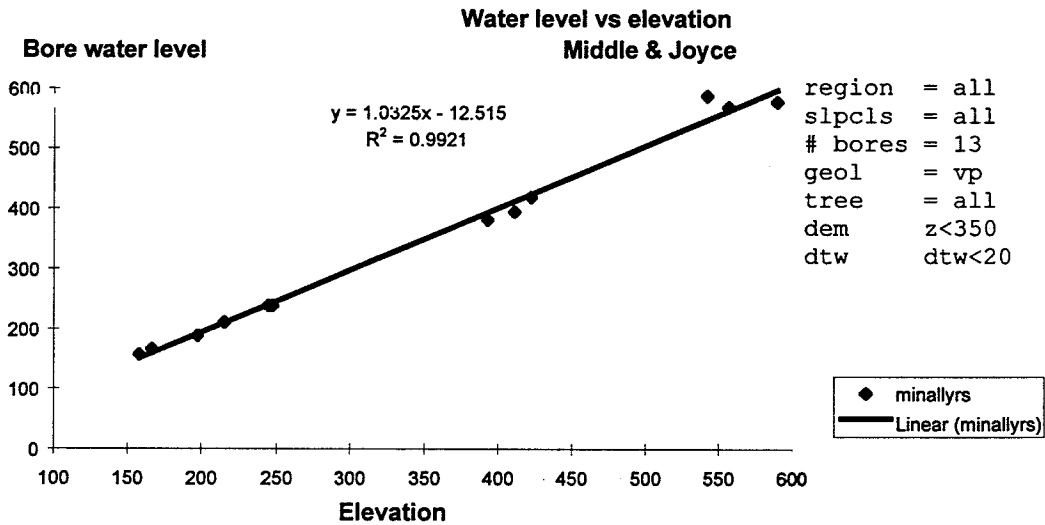
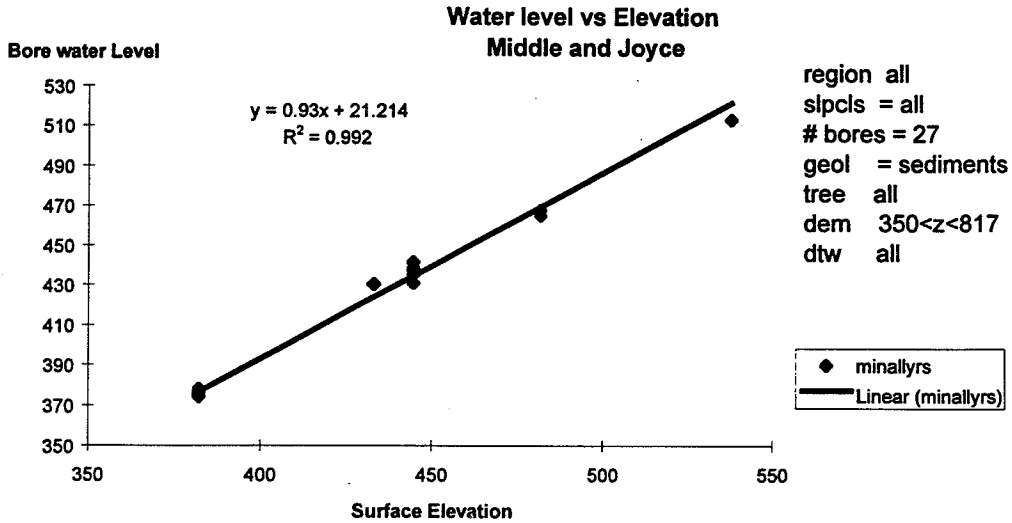


Middle & Joyce Regressions

bore set	elevation min	elev-max	#bores	geology	tree class	dtw	slope class	a	b
East Loddon Campaspe Plains	80	250	260	alluvium	all	all	all	.93	+3.6
all	130	400	24	granites	all	all	all	1.03	-10.2
all	70	150	20	fractured rock	all	all	all	1.09	-35.6
all	150	900	20	fractured rock	all	all	all	.865	+11.87
all	188	350	62	sediments	all	all	all	.98	-3.24
all	350	817	27	sediments	all	all	all	.93	+21
all	188	350	13	volcanic plains	all	all	all	1.03	-12.5
all	350	817	6	volcanic plains	all	all	all	1.12	-59

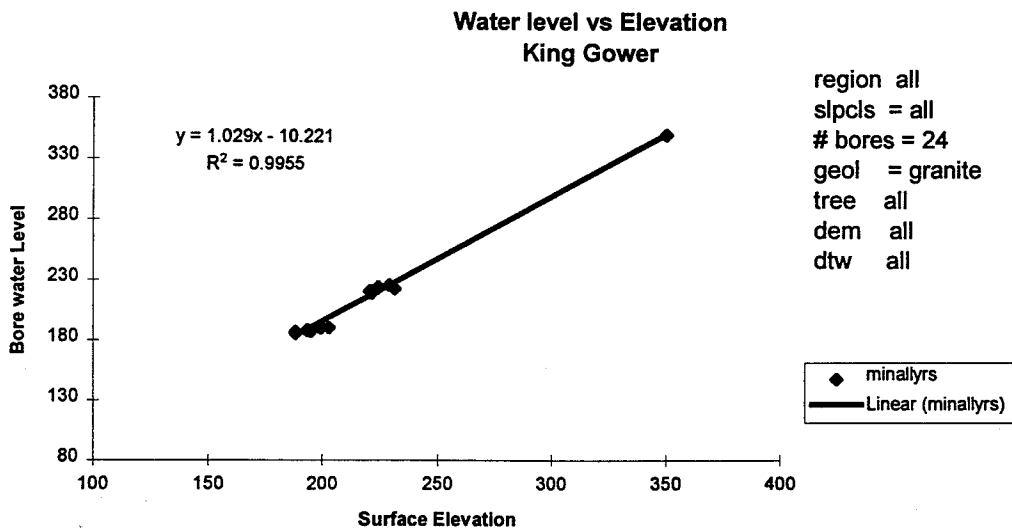
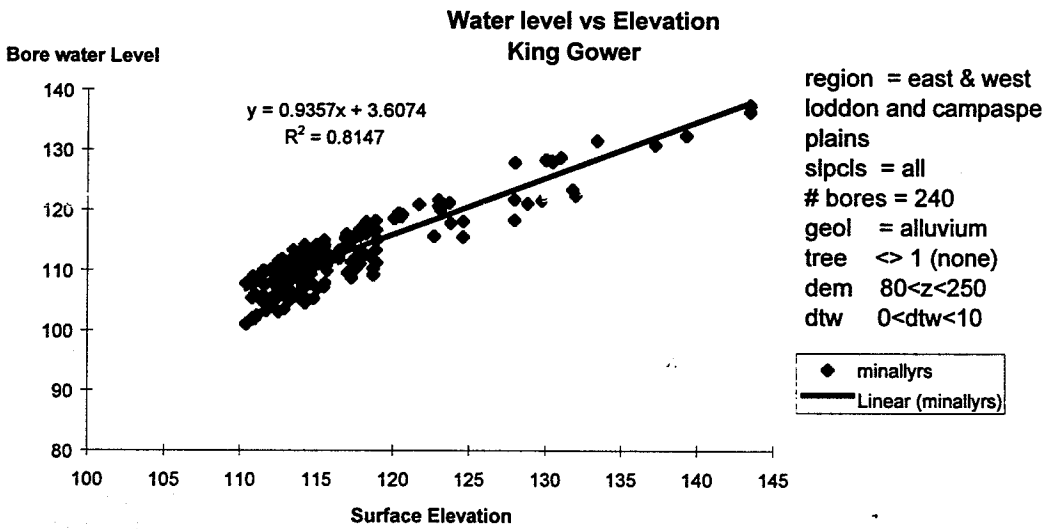


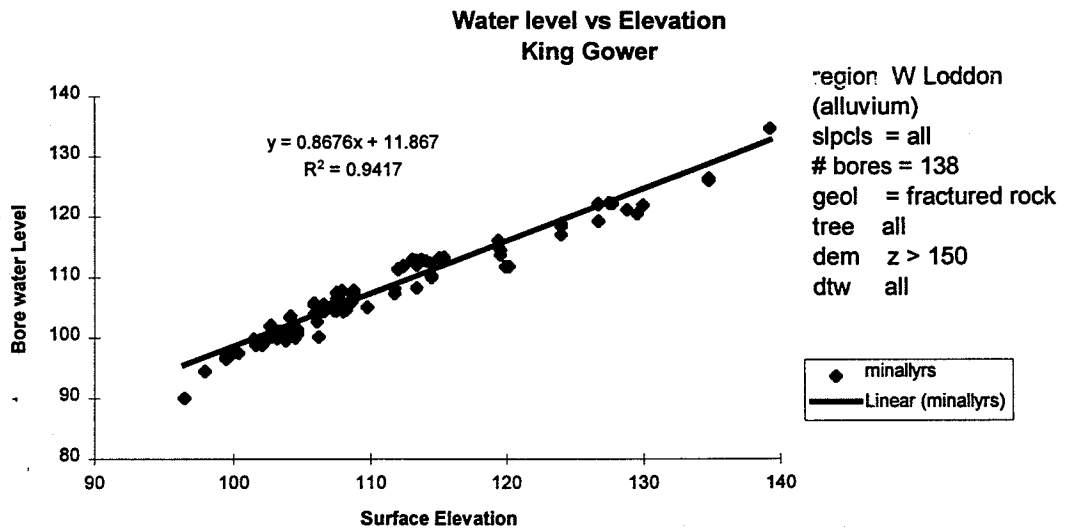
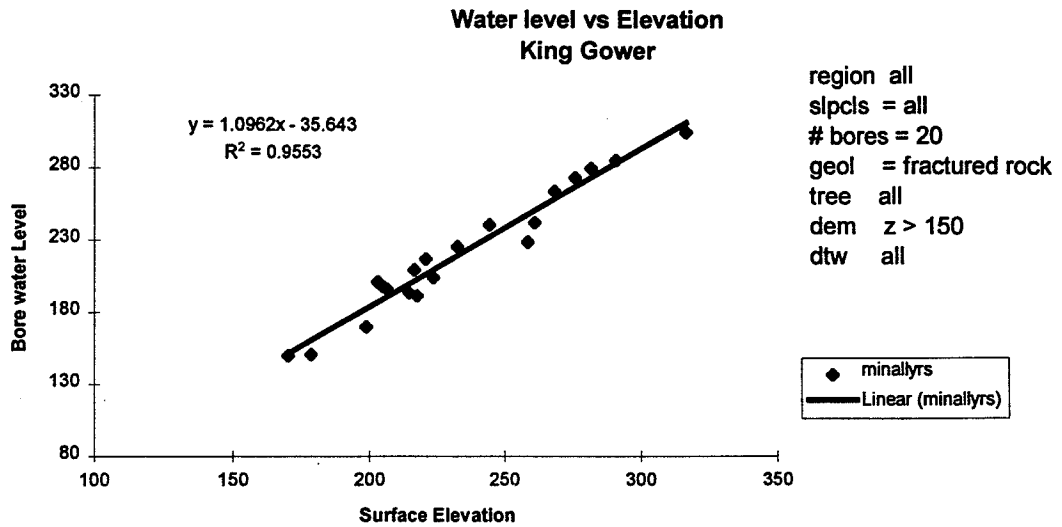


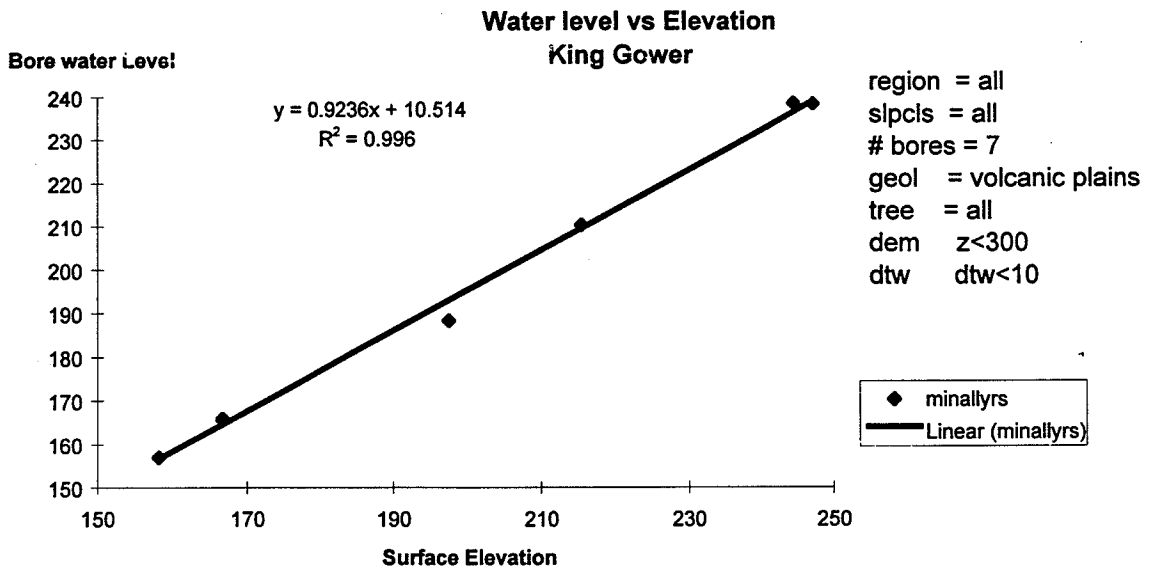
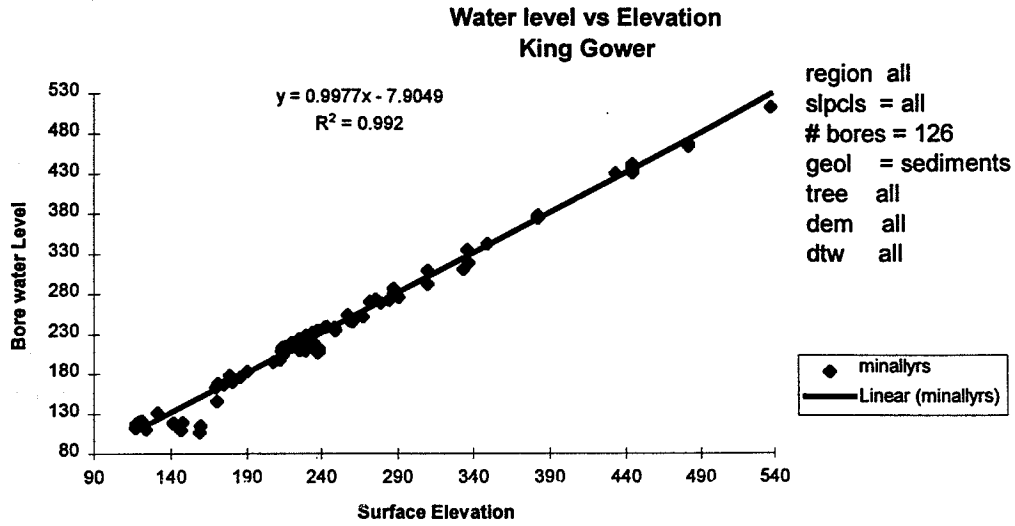


King Gower Regressions

bore set	elevation min	elev-max	#bores	geology	tree class	dtw	slope class	a	b
East Loddon Campaspe Plains	80	250	260	alluvium	all	all	all	.9903	-2.8
all	70	900	240	sediments	all	all	all	0.97	-7.9
all	130	400	24	granites	all	all	all	1.03	-10.2
all	70	300	7	volcanics	all	dtw<10	all	0.92	+10.5
all	70	150	20	fractured rock	all	all	all	1.09	-35.6
all	150	900	20	fractured rock	all	all	all	.865	+11.87

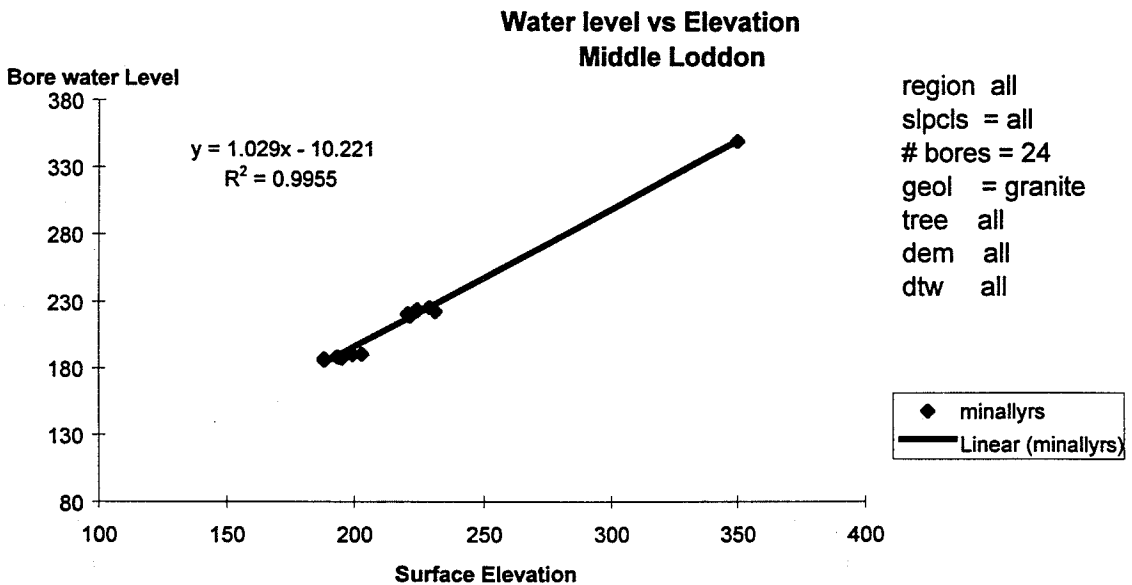
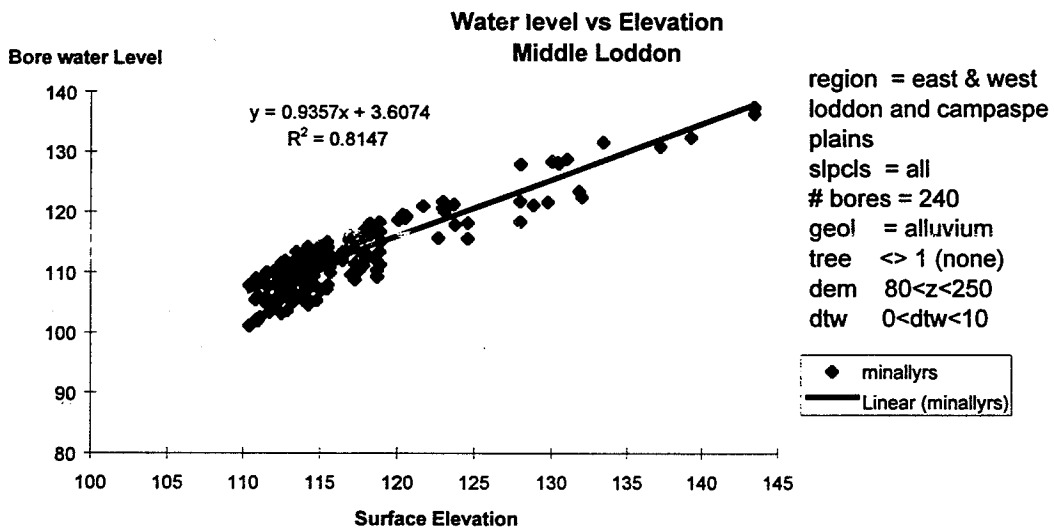


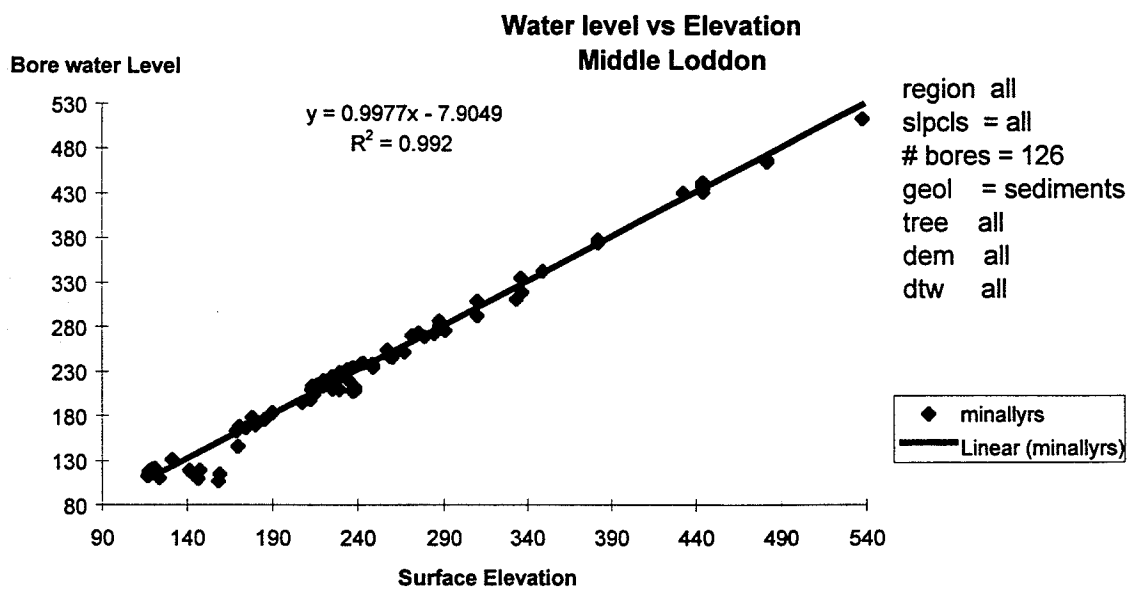
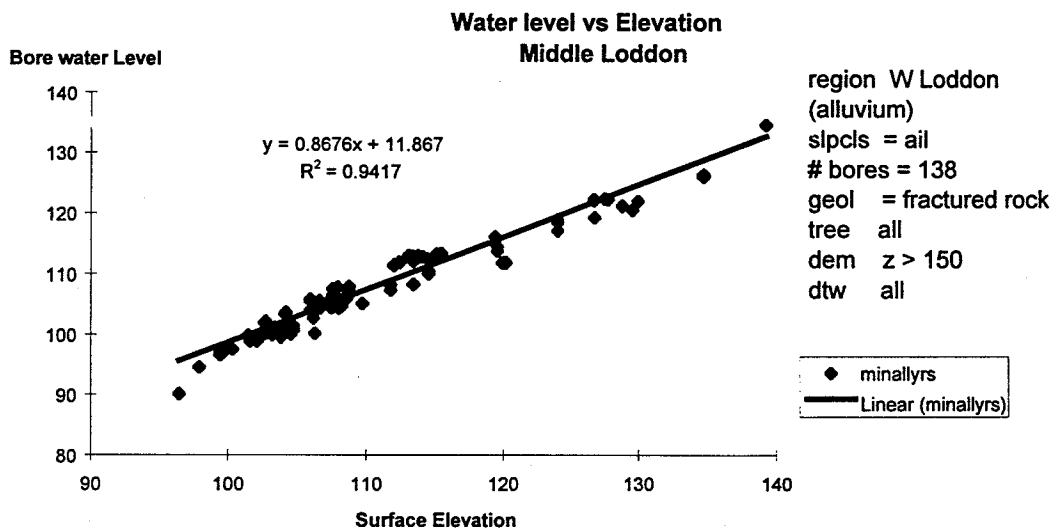
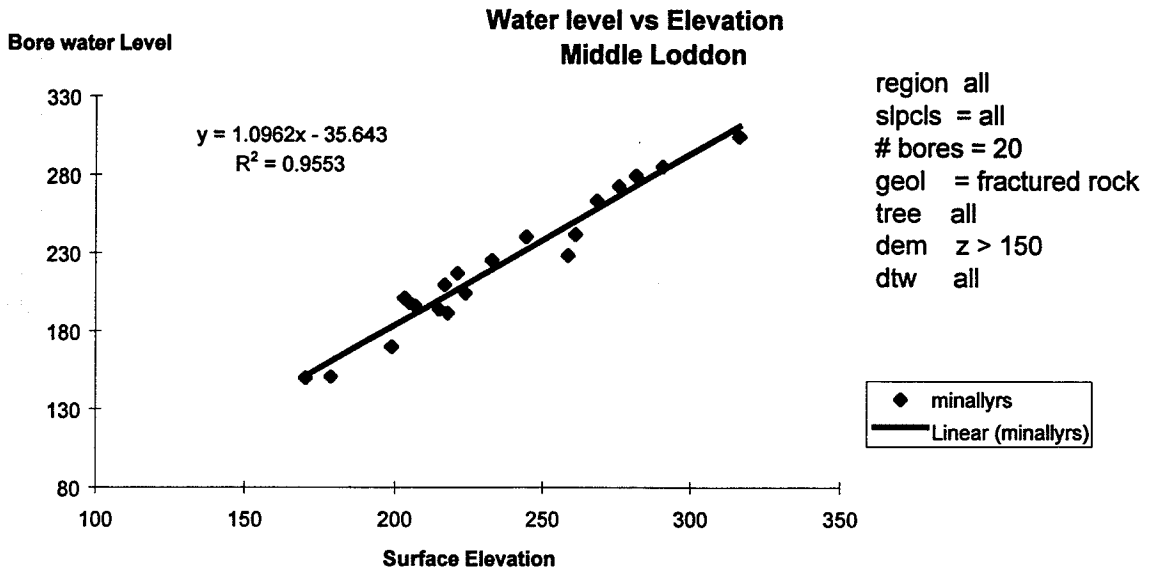


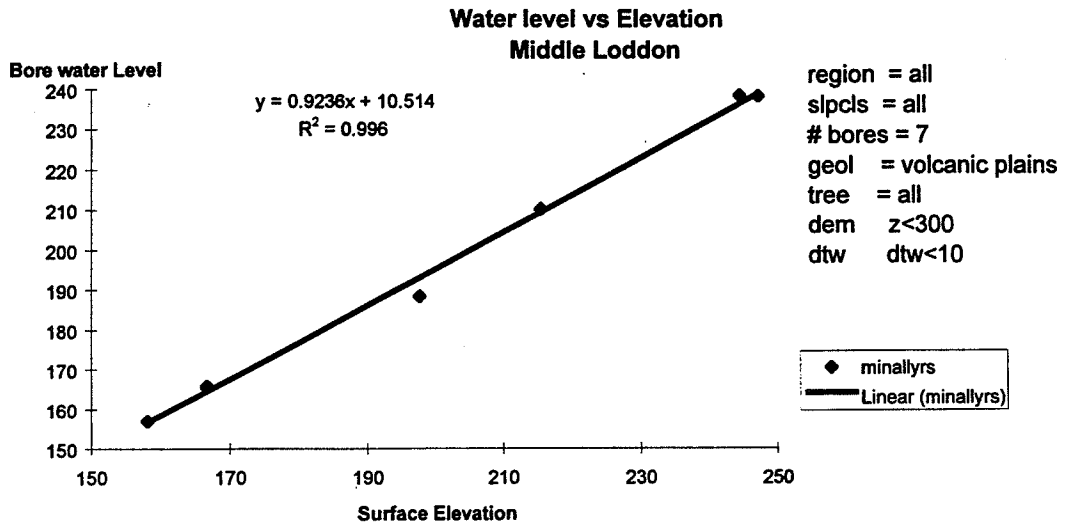


Middle Loddon Regressions

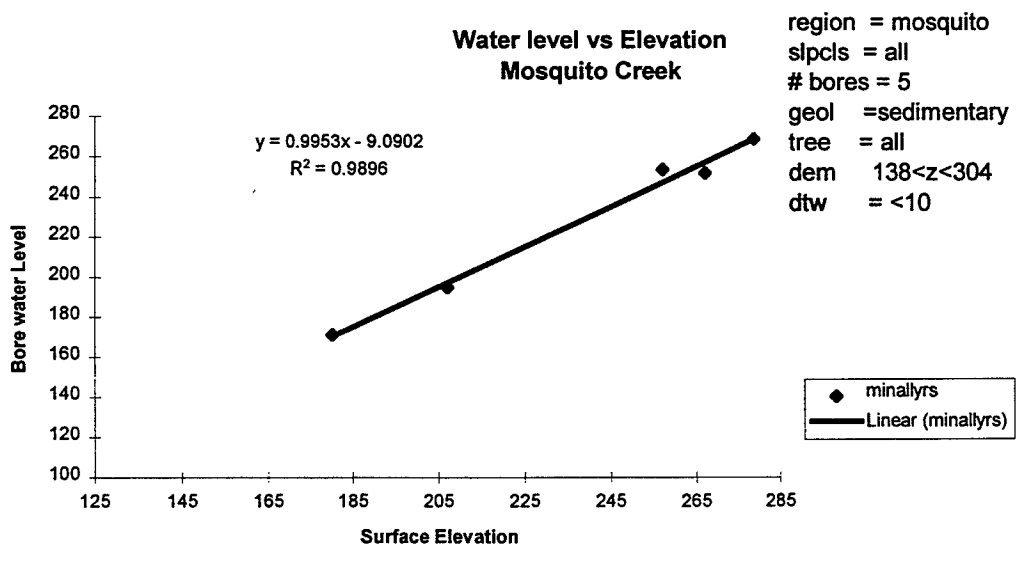
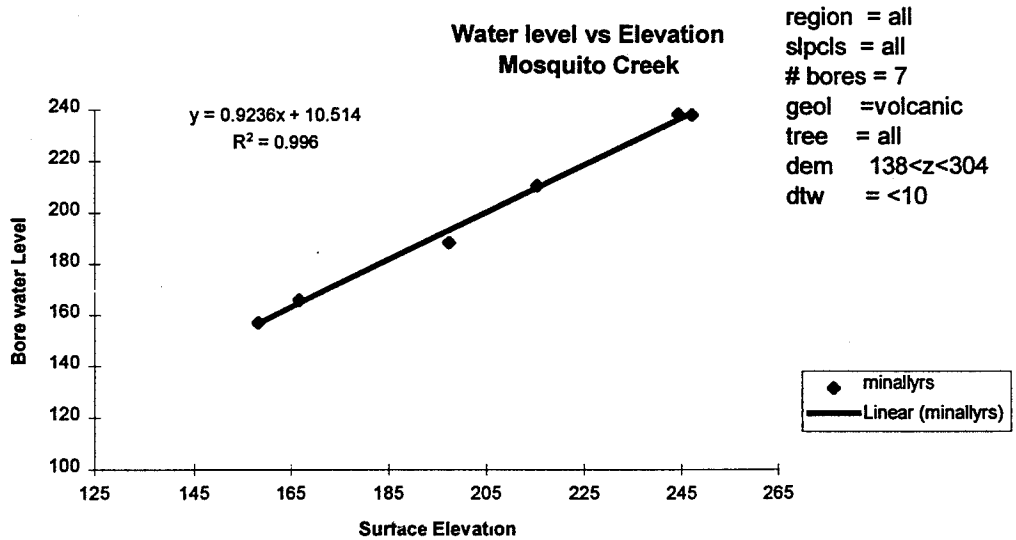
bore set	elevation min	elev-max	#bores	geology	tree class	dtw	slope class	a	b
East Loddon	80	250	260	alluvium	all	all	all	.9903	-2.8
Campaspe Plains									
all	70	900	240	sediments	all	all	all	0.97	-7.9
all	130	400	24	granites	all	all	all	1.03	-10.2
all	70	300	7	volcanics	all	dtw<10	all	0.92	+10.5
all	70	150	20	fractured rock	all	all	all	1.09	-35.6
all	150	900	20	fractured rock	all	all	all	.865	+11.87





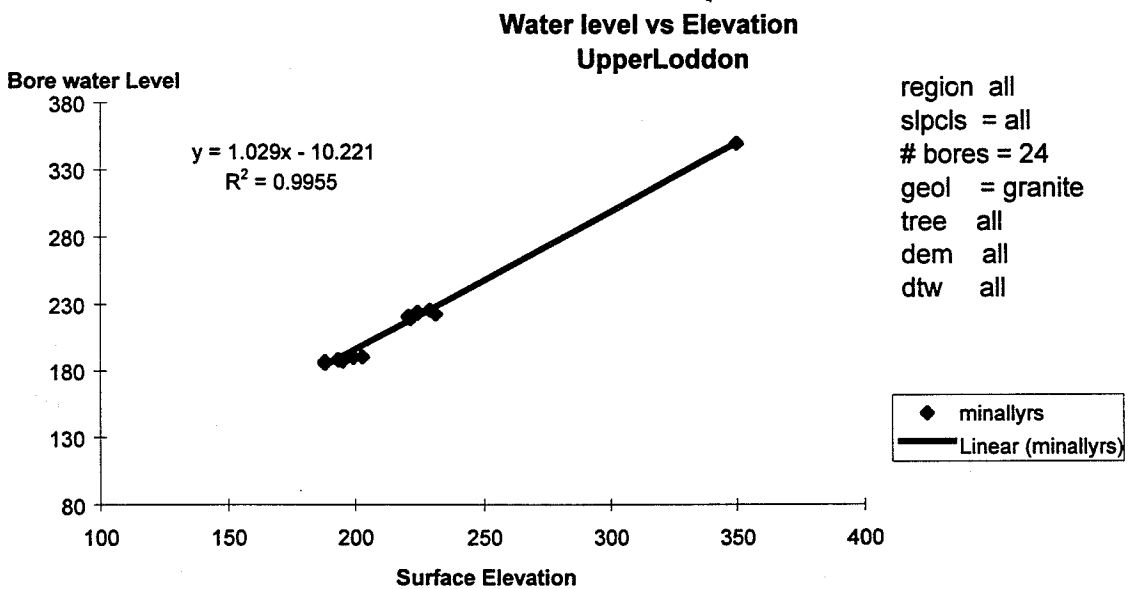
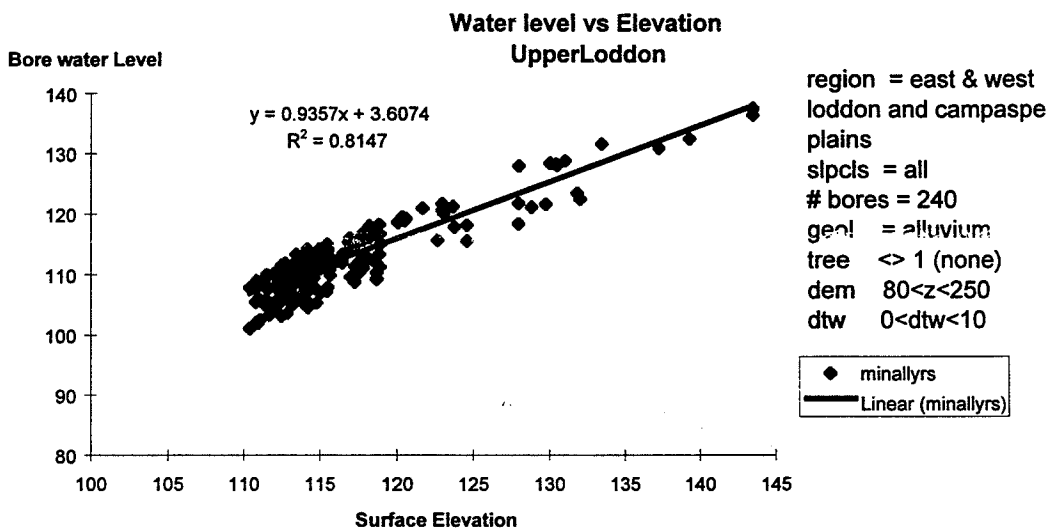


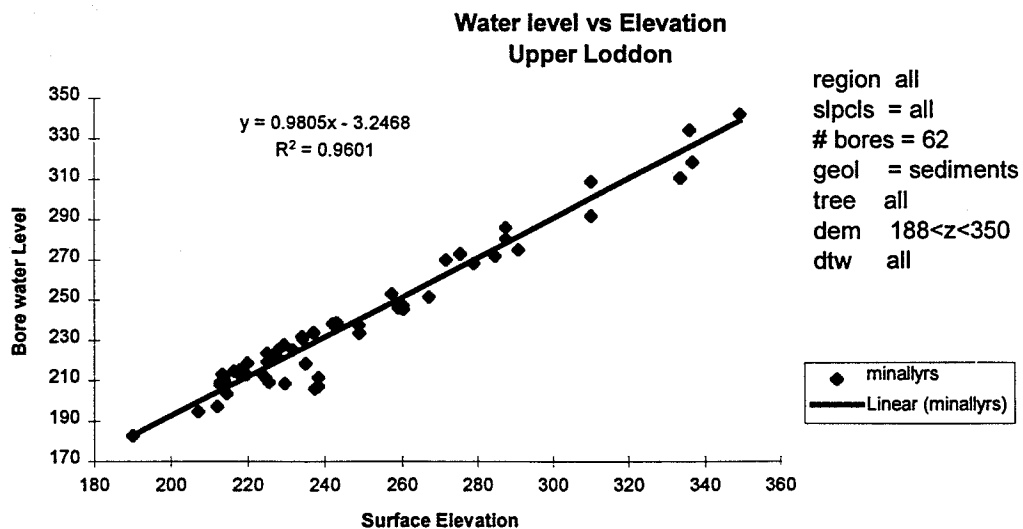
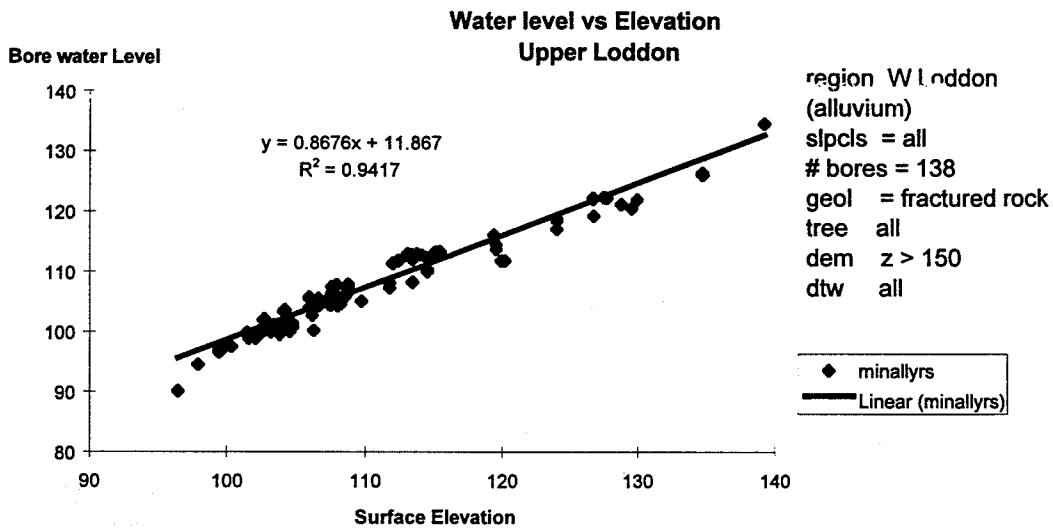
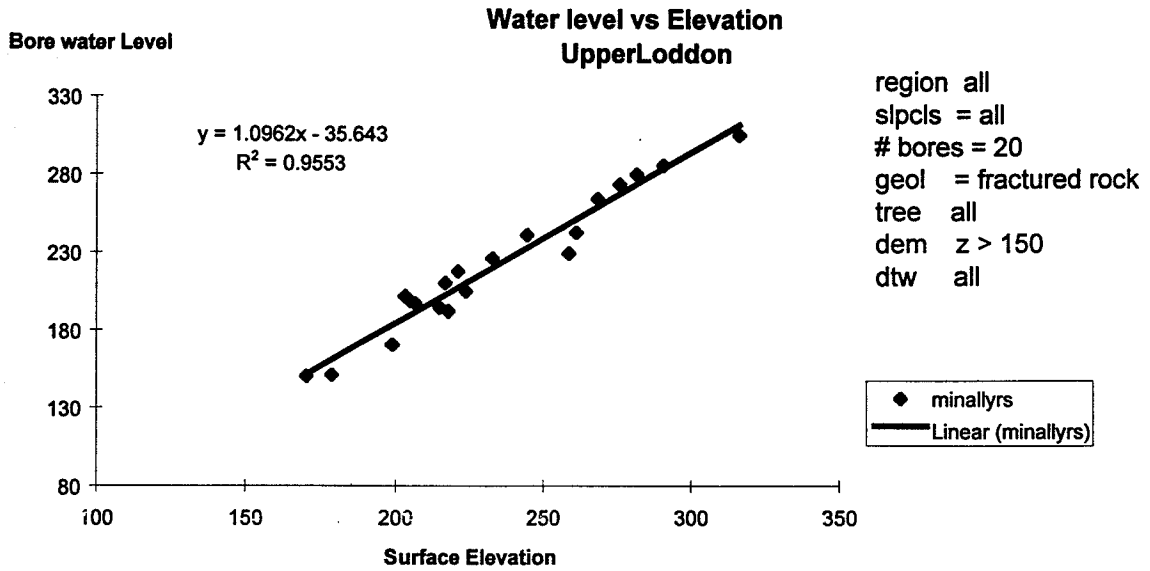
bore set	elevation min	elev-max	#bores	geology	tree class	dtw	slope class	a	b
all	138	304	7	volcanic	all	<10	all	.9236	+10.5
	130	400	64	sediments	all	<10	all	.991	2.05

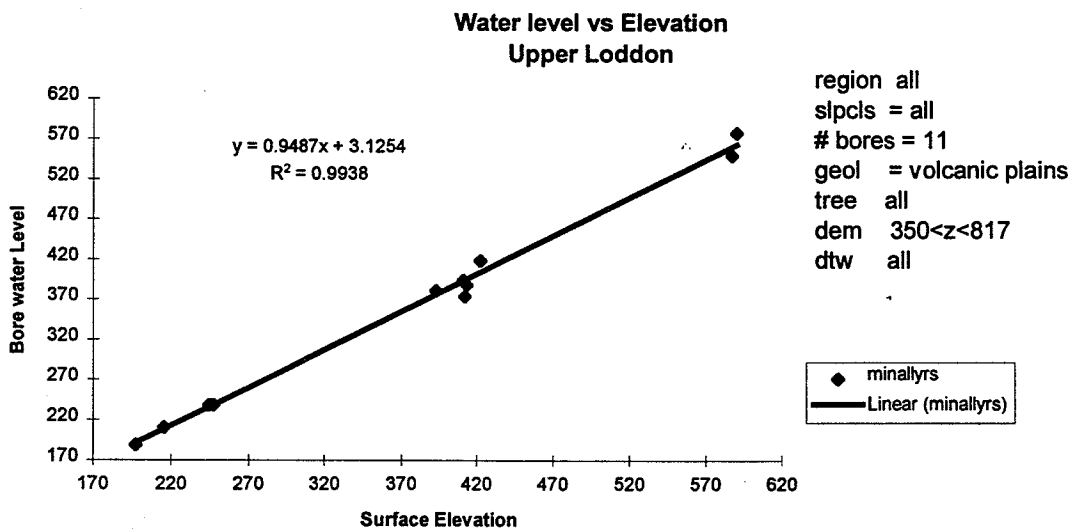
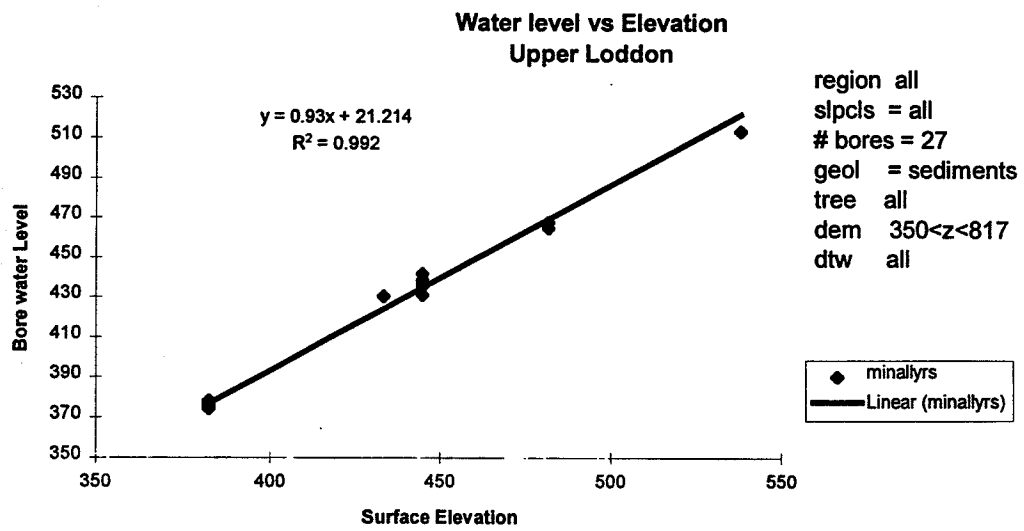


Middle Loddon Regressions

bore set	elevation min	elev-max	#bores	geology	tree class	dtw	slope class	a	b
East Loddon	80	250	260	alluvium	all	all	all	.9903	-2.8
Campaspe Plains									
all	70	900	240	sediments	all	all	all	0.97	-7.9
all	130	400	24	granites	all	all	all	1.03	-10.2
all	70	300	7	volcanics	all	dtw<10	all	0.92	+10.5
all	70	150	20	fractured rock	all	all	all	1.09	-35.6
all	150	900	20	fractured rock	all	all	all	.865	+11.87

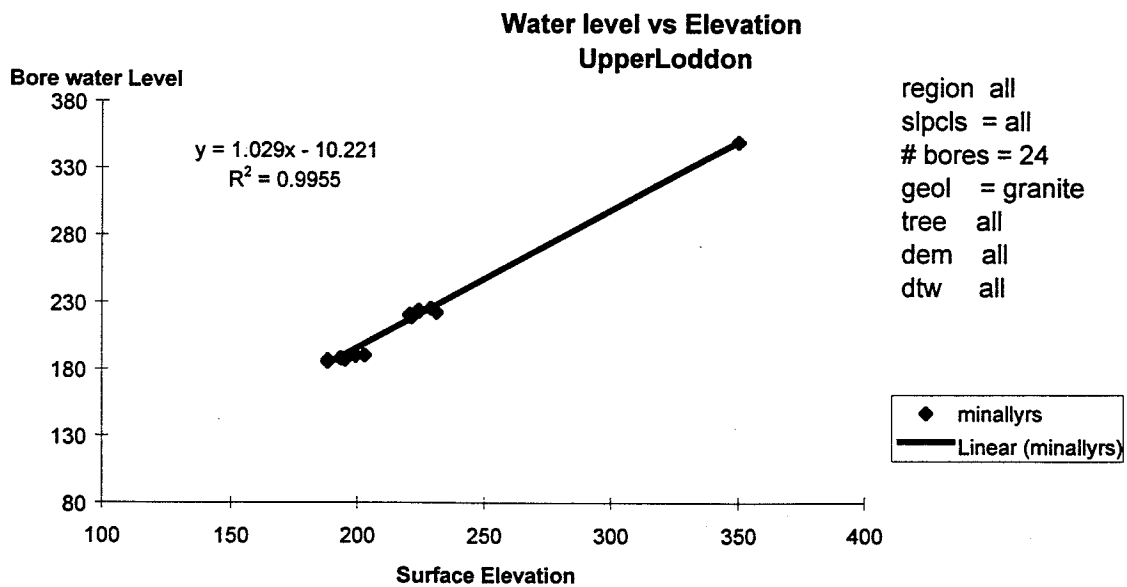
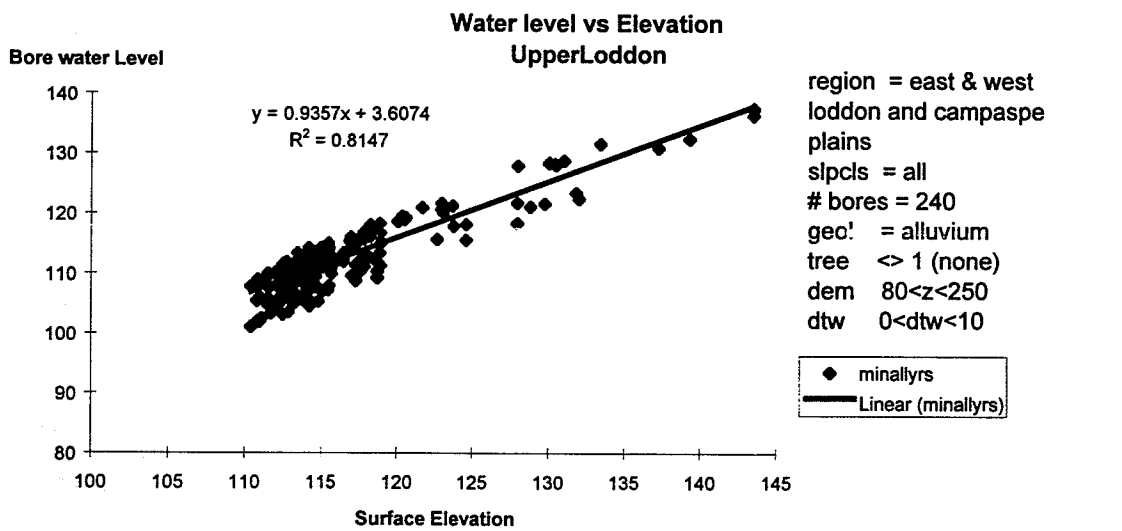


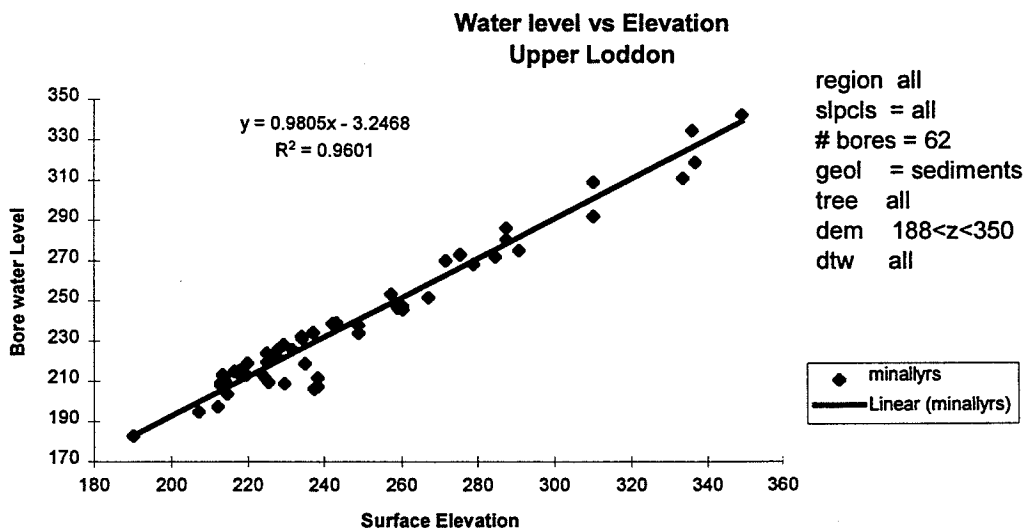
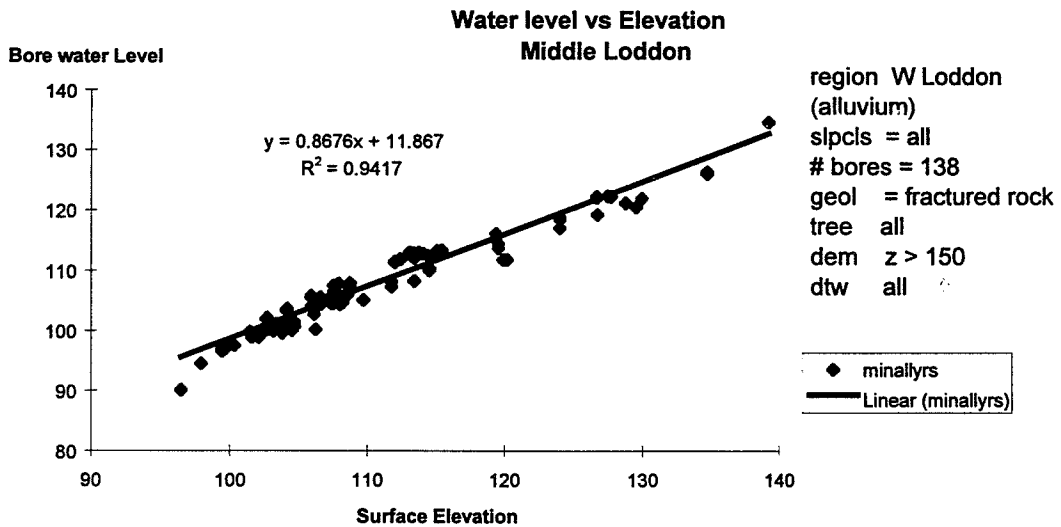
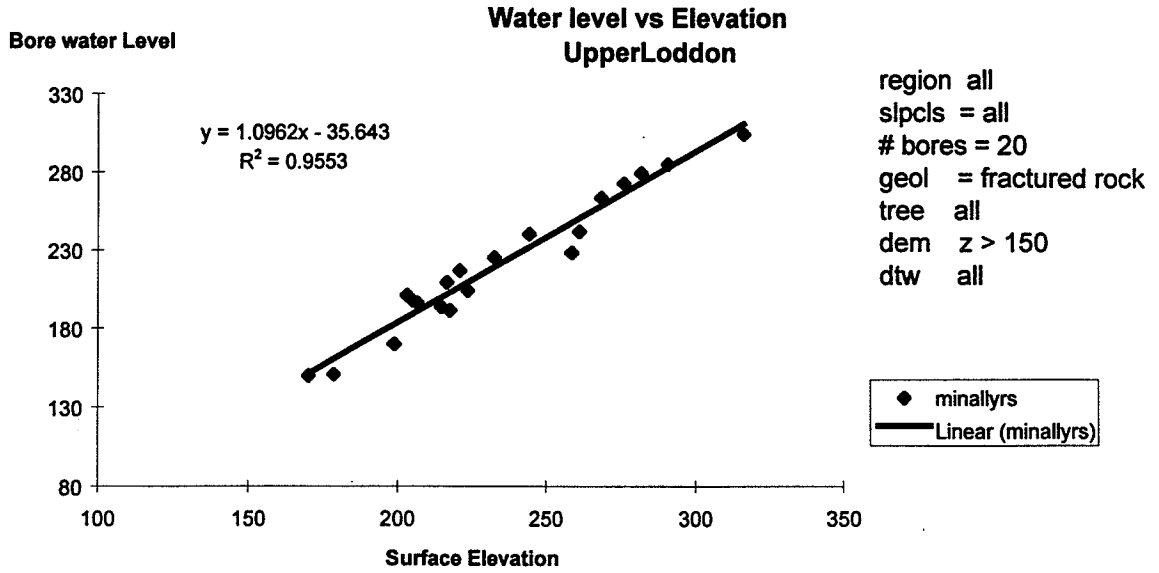


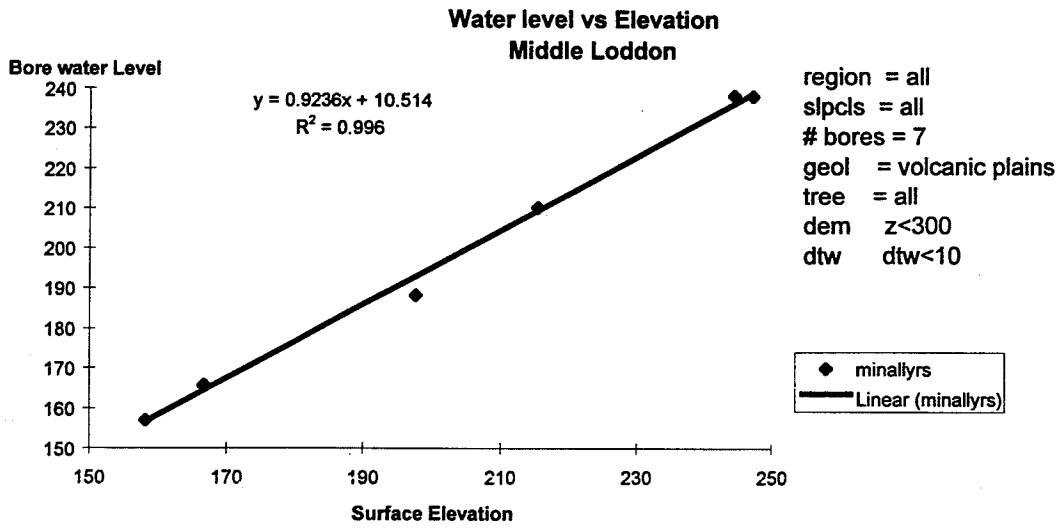


Middle Loddon Regressions

bore set	elevation min	elev-max	#bores	geology	tree class	dtw	slope class	a	b
East Loddon	80	250	260	alluvium	all	all	all	.9903	-2.8
Campaspe Plains									
all	70	900	240	sediments	all	all	all	0.97	-7.9
all	130	400	24	granites	all	all	all	1.03	-10.2
all	70	300	7	volcanics	all	dtw<10	all	0.92	+10.5
all	70	150	20	fractured rock	all	all	all	1.09	-35.6
all	150	900	20	fractured rock	all	all	all	.865	+11.87

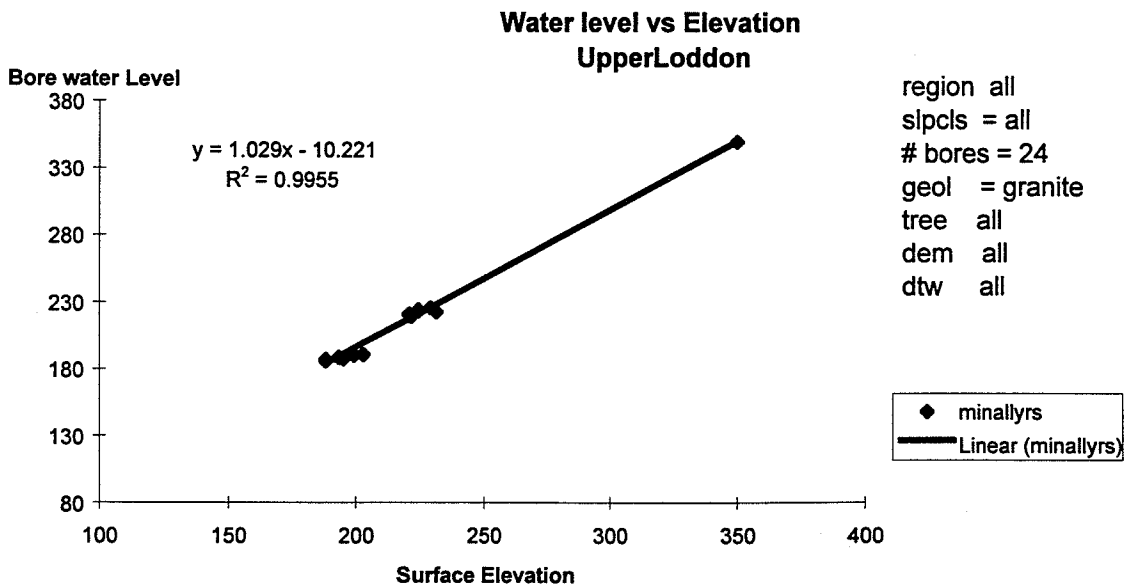
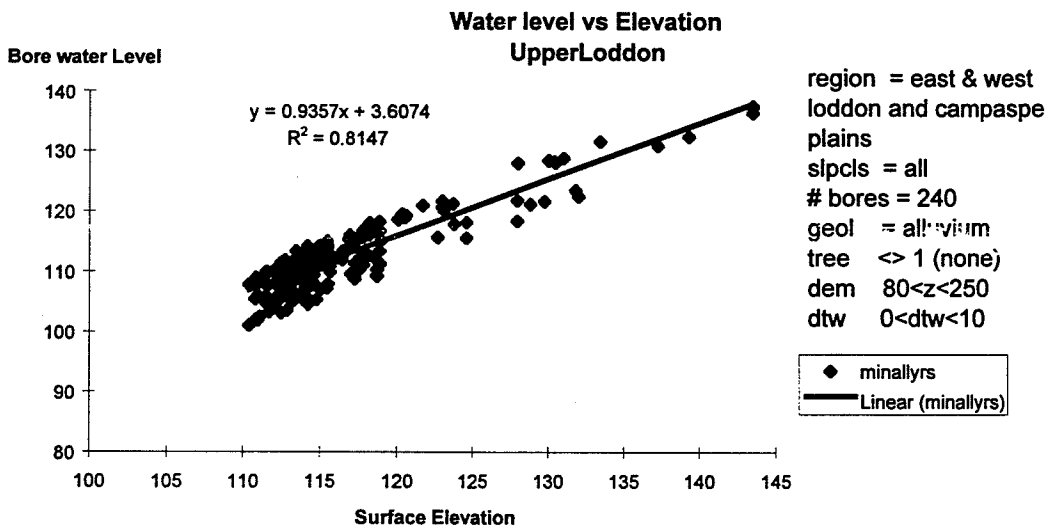


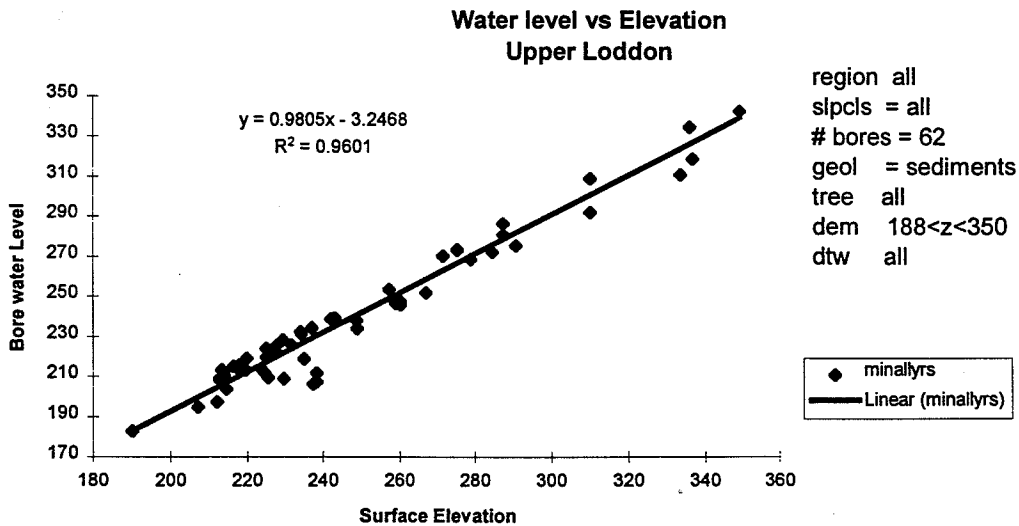
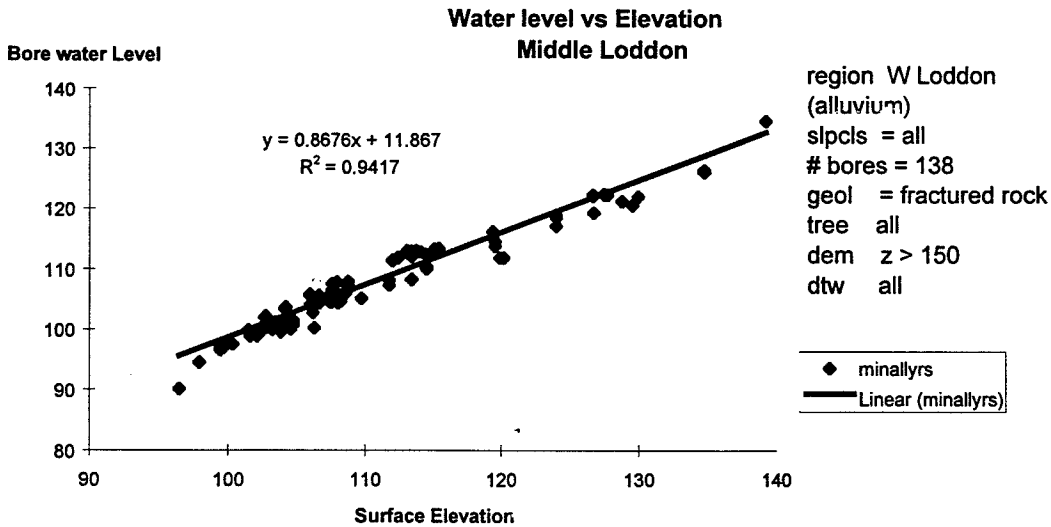
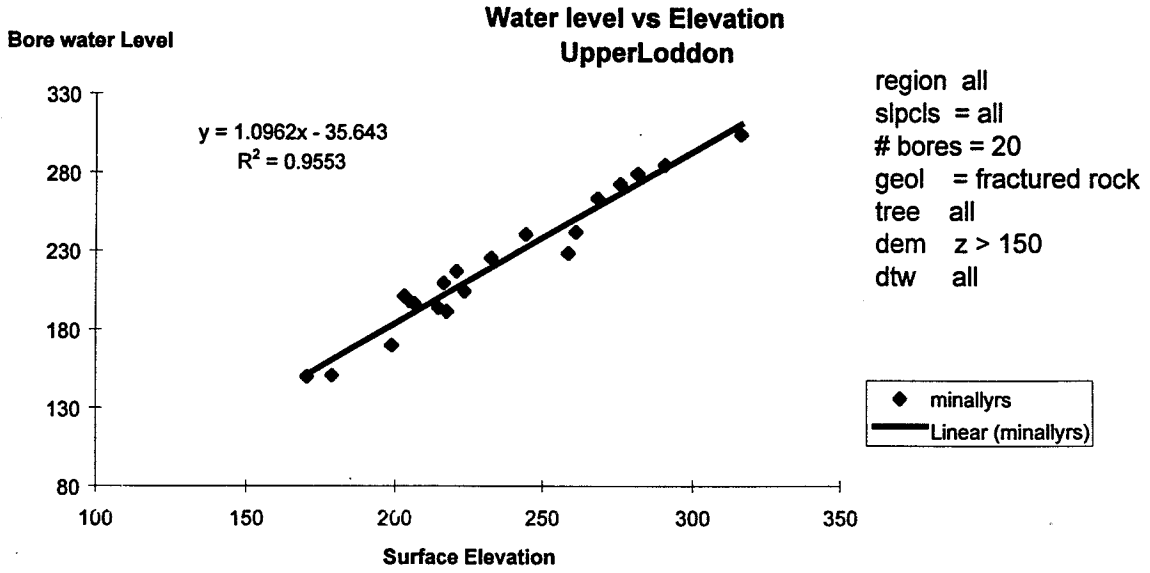


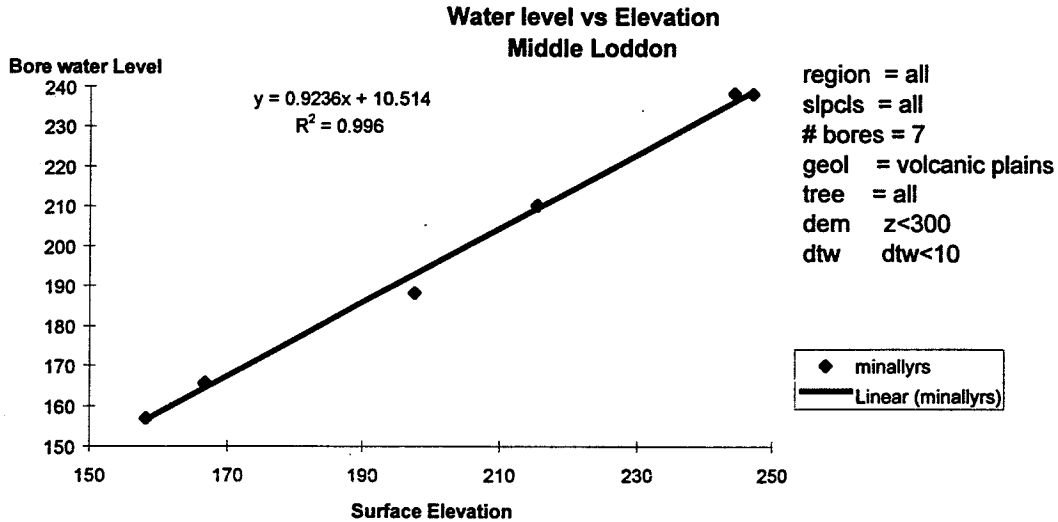


Middle Loddon Regressions

bore set	elevation min	elev-max	#bores	geology	tree class	dtw	slope class	a	b
East Loddon	80	250	260	alluvium	all	all	all	.9903	-2.8
Campaspe Plains									
all	70	900	240	sediments	all	all	all	0.97	-7.9
all	130	400	24	granites	all	all	all	1.03	-10.2
all	70	300	7	volcanics	all	dtw<10	all	0.92	+10.5
all	70	150	20	fractured rock	all	all	all	1.09	-35.6
all	150	900	20	fractured rock	all	all	all	.865	+11.87

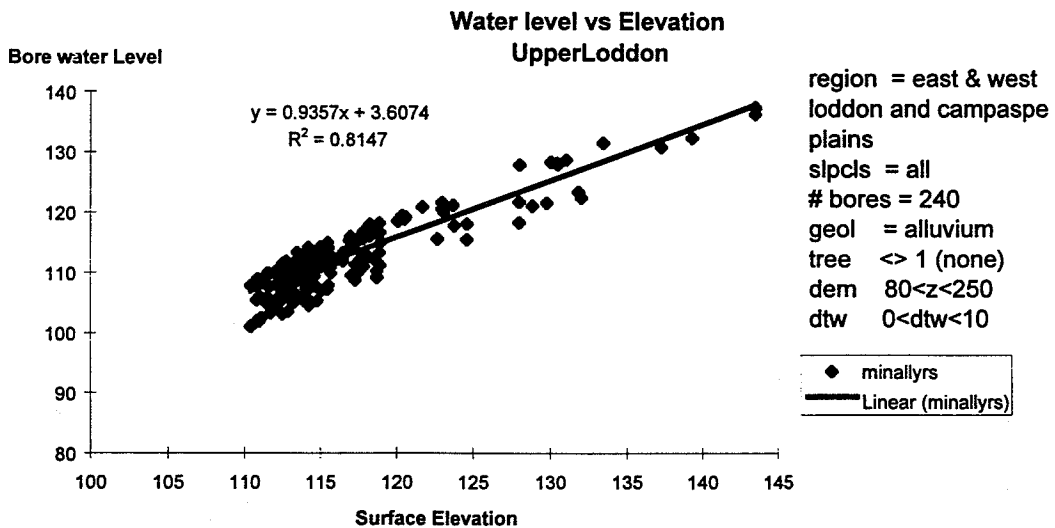


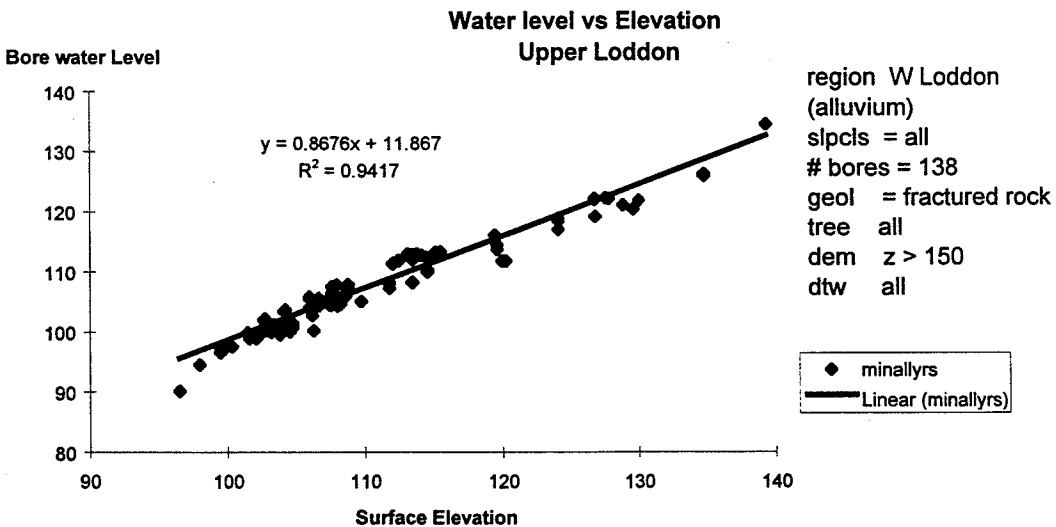
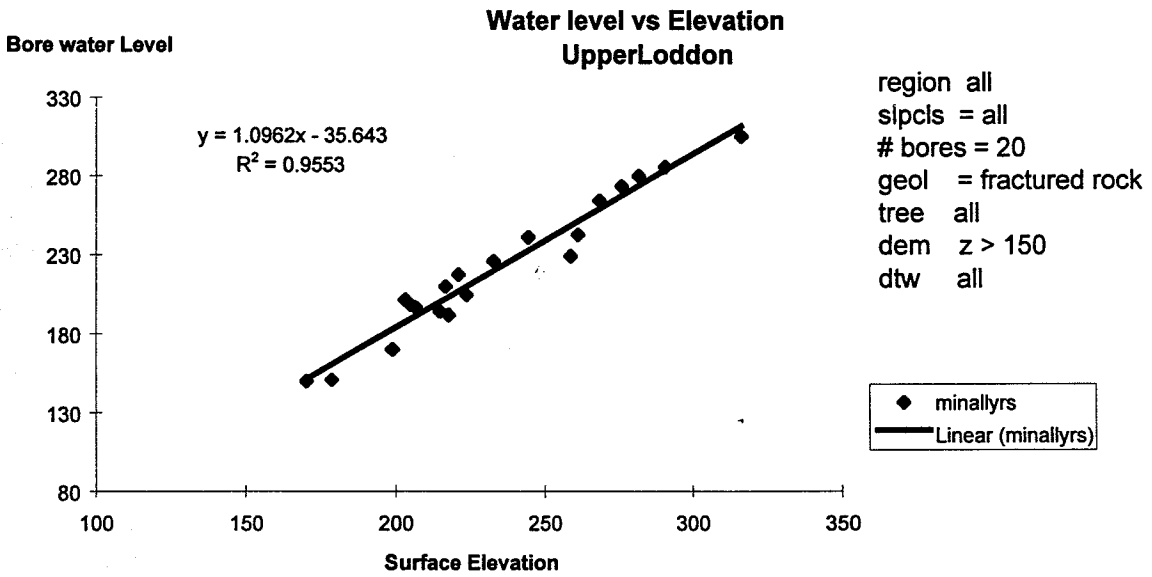
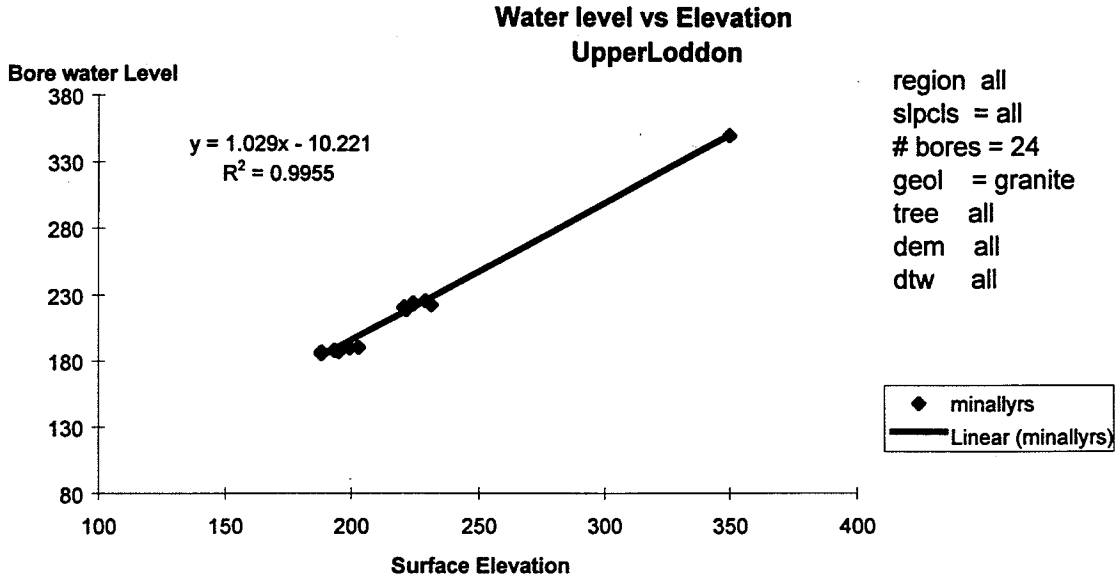


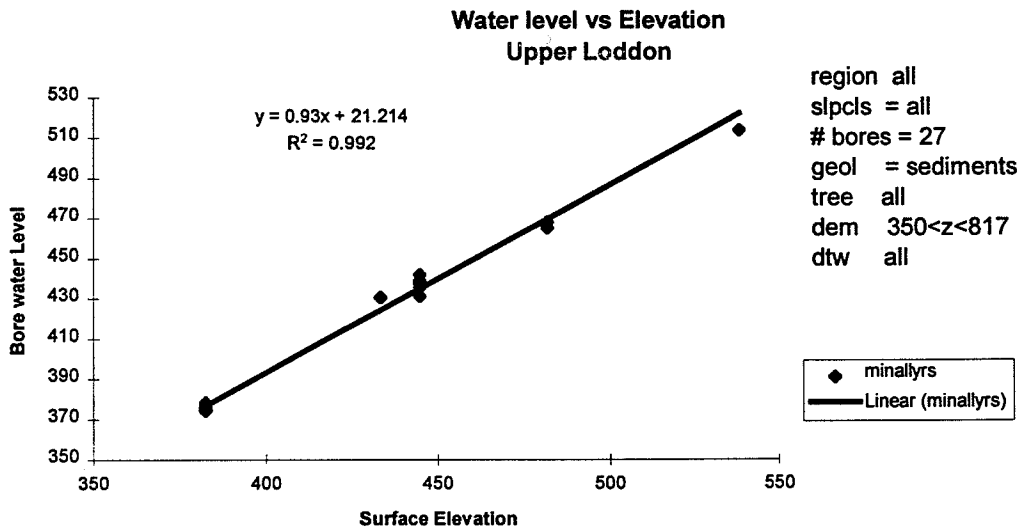
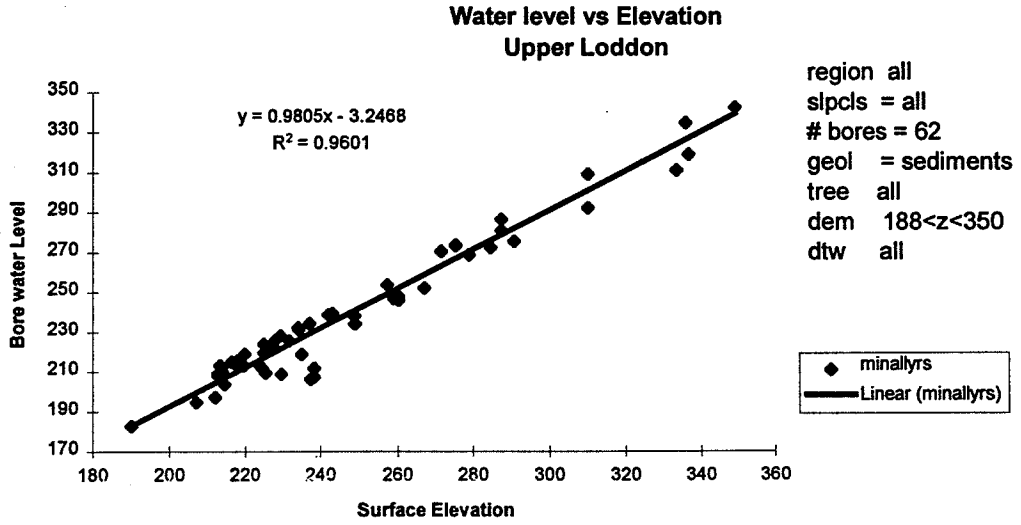


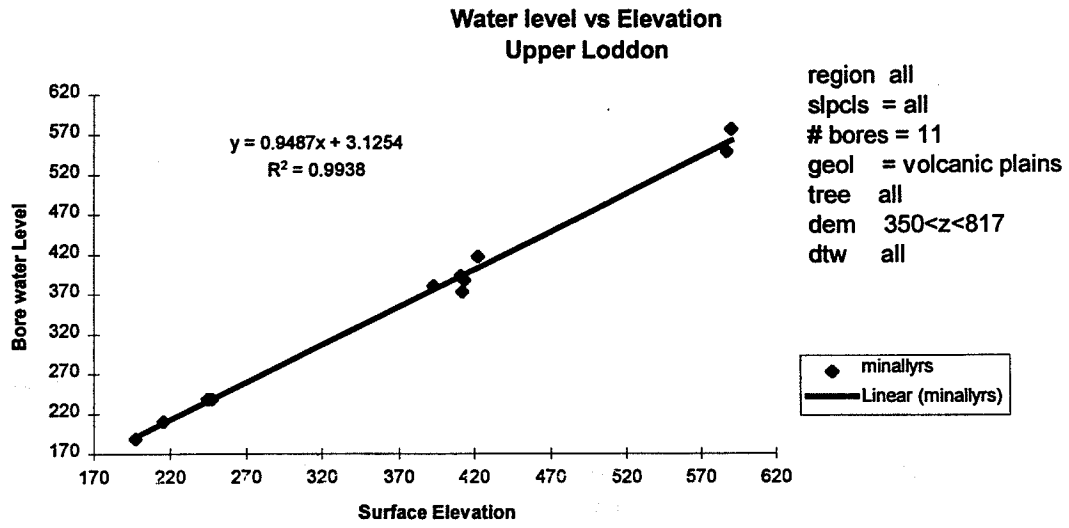
Middle Loddon Regressions

bore set	elevation min	elev-max	#bores	geology	tree class	dtw	slope class	a	b
East Loddon	80	250	260	alluvium	all	all	all	.9903	-2.8
Campaspe Plains									
all	70	900	240	sediments	all	all	all	0.97	-7.9
all	130	400	24	granites	all	all	all	1.03	-10.2
all	70	300	7	volcanics	all	dtw<10	all	0.92	+10.5
all	70	150	20	fractured rock	all	all	all	1.09	-35.6
all	150	900	20	fractured rock	all	all	all	.865	+11.87



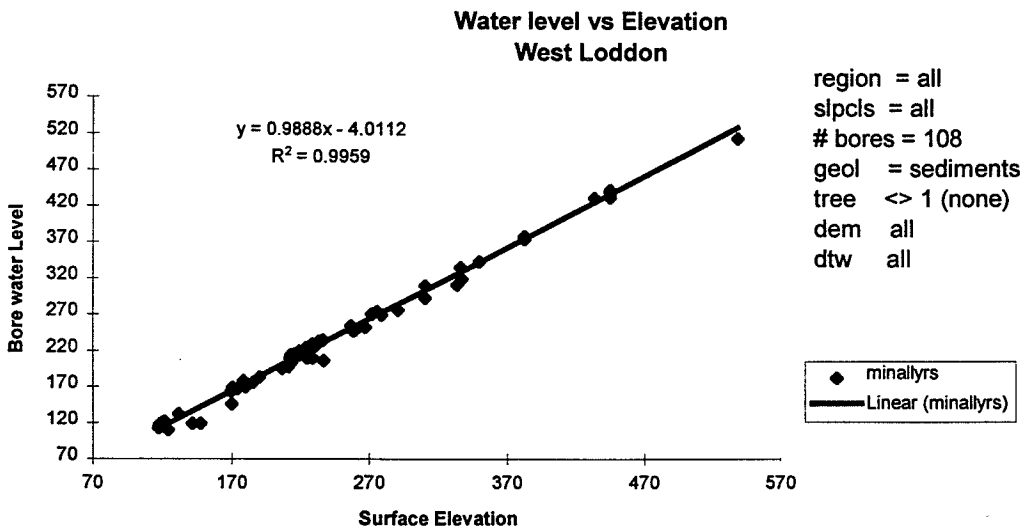
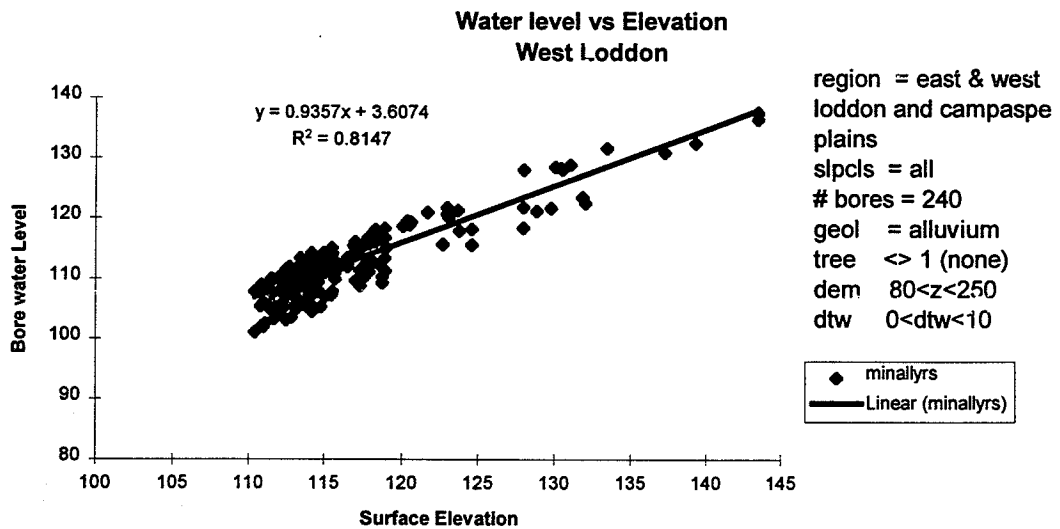


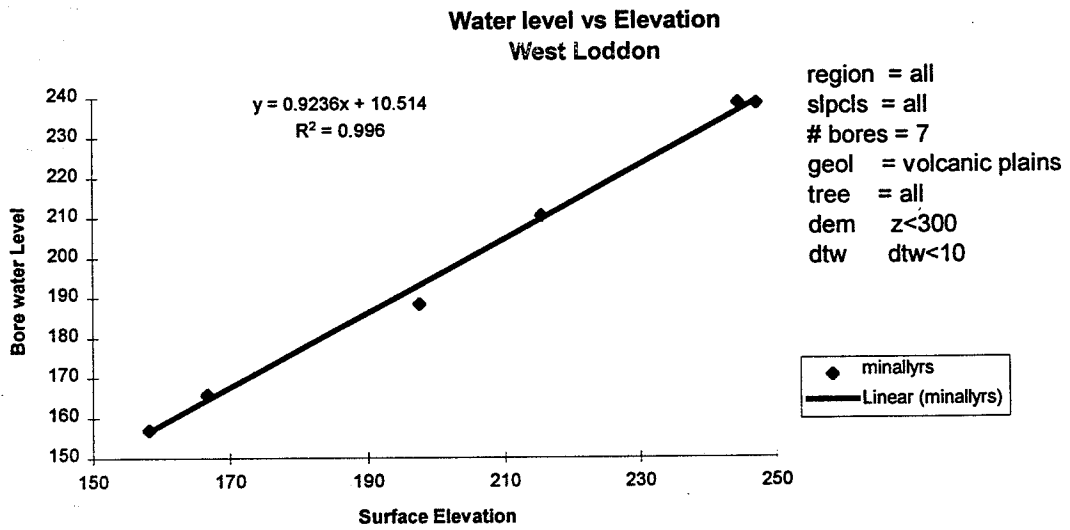
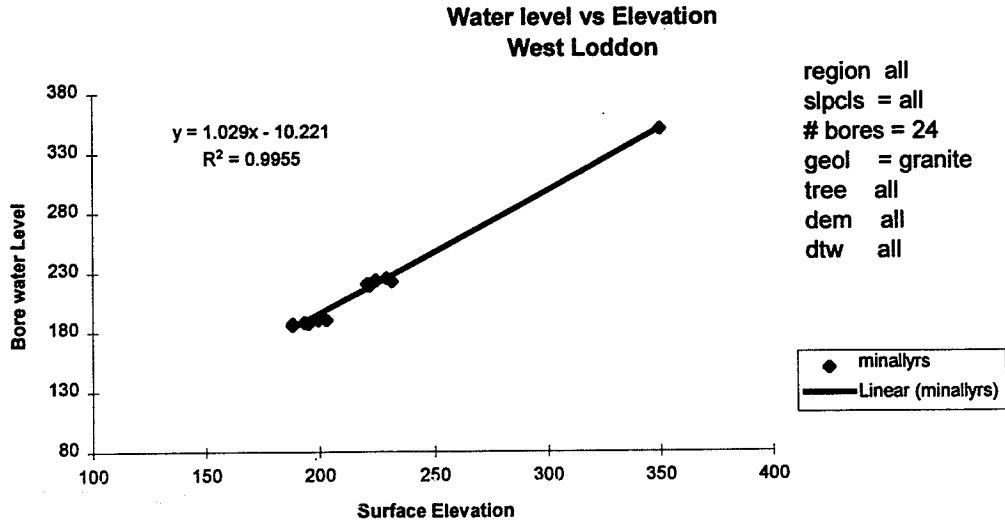




West Loddon Regressions

bore set	elevation min	elev-max	#bores	geology	tree class	dtw	slope class	a	b
East Loddon Campaspe Plains	80	250	260	alluvium	all	all	all	.9903	-2.8
all	70	900	108	sediments	< 1 none	all	all	0.97	+1.03
all	130	400	24	granites	all	all	all	1.03	-10.2
all	70	300	7	volcanics	all	dtw<10	all	.092	+10.5





IV. Summary of Hydrographic Databases

The following is a summary of the hydrographic databases generated as a result of the Loddon-Campaspe project. A description of the contents of the databases is given, along with the directory location of the database. These databases are available on DAT tape backup within the same directory structure as presented below. All databases are in MSAccess format.

c:\data\bores\ATTRIB.mdb

753 Kb

Ec, tds, number of bores and spatial attributes for RWC bores that appear in the chemical data table and have defined attributes. Summary statistics of ec and tds by subcatchment and geology.

c:\data\bores\CHEMICAL.mdb

18.9 Mb

Original RWC chemical data (ec, tds, etc) for 38,102 bores, and locational data for 17,426 RWC bores.

c:\data\bores\DISCHARGE.mdb

3.0 Mb

Bureau of Meteorology rainfall station numbers, for stations nearest to discharge stations, and annual and monthly rainfall data for those stations. Locational data for stream discharge stations is also included.

c:\data\bores\RAMSIS.mdb

491 Kb

Summary statistics and number of bores for ec and tds by subcatchment and geology.

c:\data\bores\RECHG.mdb

928 Kb

Seasonal recharge means and annual recharge, by geology, subcatchment and HGU, for DCNR and RWC bores. Also relationship between recharge and conductivity by bore. subcatchment.

c:\data\bores\SHAREBOR.mdb

3.1 Mb

Old/new bore id correspondence table, locational data and attribute data for bores shared by chemical data table and attribute data table.

c:\data\bores\dcnr\DCNR.mdb

1.1 Mb

DCNR bores with 22,904 water level time series records converted from Excel (depth to water) format, with DCNR locational and attribute data.

c:\data\bores\dcnr\FINAL-DC.mdb **1.6 Mb**

Contains recharge for both RWC and DCNR bores. Final DCNR bore data used for regression analyses by bore id, geology and subcatchment. Seasonal fluctuation data and summary statistics for water level fluctuations by geology, HGU and vegetation for DCNR bores.

c:\data\bores\dcnr\boreaces\LCMASTER.mdb **163 Kb**

Original DCNR bore databases of locational and attribute data for 494 bores.

c:\data\bores\dcnr\original\GWBORE.mdb **41.4 Mb**

Original DCNR composite database of RWC and DCNR bores as it was received at commencement of project in 3/95. Contains many queries and tables not required by this project.

c:\data\bores\rwc\FINAL.mdb **5.3 Mb**

Recharge estimates from RWC bores. Final RWC bore data used for regression analyses by bore id, geology and subcatchment. Seasonal fluctuation data and summary statistics for water level fluctuations by geology, HGU and vegetation classes for RWC bores.

c:\data\bores\dcnr\RGRSIONS.mdb **327 kb**

Locational and attribute data for 320 RWC bores used in regression analyses. Subsets of bores, locations and attributes by geology, HGU, vegetation and catchment used in regression analyses.

SALTSCAT.mdb **416 kb**

Bore tds and ec, and averages for all subcatchments, and by geological formations.

STREAMS.mdb **704 kb**

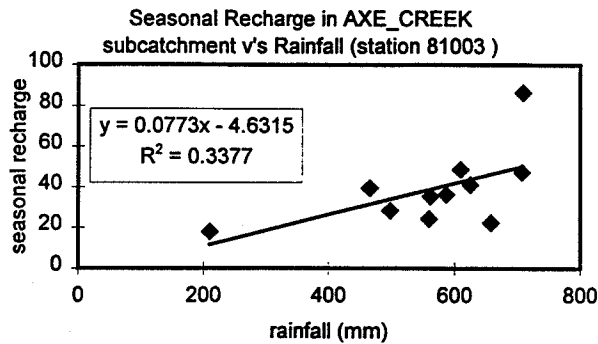
Monthly stream discharge, and precipitation data, with analysis of their relationship by station pairs.

V. Seasonal Recharge versus rainfall

An expected relationship between local rainfall and recharge was investigated through linear and nonlinear regression analyses by associated the bores in a given subcatchment with the nearest available rainfall recording station. There was a surprisingly weak general relationship between these two variables. These relationships were therefore not relied upon in the development of the flow net models, but are reported below.

SUBCATCHMENT	No. of data pts.	Regress TYPE	Regress EQUATION	R ²
ALL		31 Linear	$y = 0.1403 x + 8.7773$	0.2113
	1961 to 1991	Quadratic	$y = 0.0005 x^2 - 0.4186 x + 161.66$	0.3879
AXE_CREEK		11 Linear	$y = 0.0773 x - 4.6315$	0.3377
	1981 to 1991	Quadratic	$y = 0.0002 x^2 - 0.1397 x + 39.72$	0.4286
BENDIGO_MYERS		25 Linear	$y = 0.1577 x + 0.1402$	0.2817
	1961 to 1991	Quadratic	$y = 0.0005 x^2 - 0.4595 x + 175.09$	0.5038
BETBET_CRK		13 Linear	$y = 0.0596 x + 38.187$	0.017
	1979 to 1991	Quadratic	$y = 0.0005 x^2 - 0.398 x + 133.62$	0.0521
BULLAUL		8 Linear	$y = -0.0037 x + 34.79$	0.0008
	1984 to 1991	Quadratic	$y = 0.0003 x^2 - 0.3406 x + 131.47$	0.038
CAMEL_RNGE		7 Linear	$y = 0.1264 x + 6.9114$	0.0555
	1985 to 1991	Quadratic	$y = -0.0005 x^2 + 0.7353 x - 167.15$	0.0618
CAMP_PLAIN		0.028 Linear	$y = 0.0257 x + 141.46$	0.0027
	1964 to 1991	Quadratic	$y = 0.0006 x^2 - 0.7398 x + 348.58$	0.126
E_LOD_PLAIN		22 Linear	$y = 0.0904 x + 29.933$	0.106
1 outlier removed	1964 to 1991	Quadratic	$y = 0.0003 x^2 - 0.3099 x + 141.63$	0.2099
FOREST		5 Linear	$y = 0.0784 x - 0.7954$	0.2567
1 outlier removed	1987 to 1991	Quadratic	$y = 0.0016 x^2 - 1.7385 x + 516.43$	0.7663
KING_KORONG		13 Linear	$y = 0.0774 x + 20.013$	0.0263
1 outlier removed	1976 to 1991	Quadratic	$y = 0.0012 x^2 - 1.1906 x + 353.72$	0.0997
MID_LODDON		10 Linear	$y = -0.0424 x + 65.245$	0.262
	1976 to 1991	Quadratic	$y = -0.0012 x^2 + 1.3044 x - 284.03$	0.3125
MIDDLE_JOYCE		4 Linear	$y = -0.0601 x + 41.54$	0.8772
	1987 to 1991	Quadratic	$y = 0.0002 x^2 - 0.3443 x + 122.78$	0.9356
MOSQUITO		9 Linear	$y = 0.1108 x - 26.284$	0.4364
	1983 to 1991	Quadratic	$y = 0.0009 x^2 - 1.0131 x + 301.76$	0.6445
MYRTLE		9 Linear	$y = 0.1214 x - 13.79$	0.2398
	1983 to 1991	Quadratic	$y = 0.0011 x^2 - 1.2364 x + 382.53$	0.3788
TULLAROOP		7 Linear	$y = 0.1274 x + 64.11$	0.0292
	1985 to 1991	Quadratic	$y = 0.0054 x^2 - 6.1066 x + 1846.1$	0.3729
UP_CAMPASPE		7 Linear	$y = -0.0921 x + 91.658$	0.4552
	1985 to 1991	Quadratic	$y = 0.0003 x^2 - 0.4006 x + 179.86$	0.4804
UP_LODDON		14 Linear	$y = 0.0061 x + 22.921$	0.0094
	1978 to 1991			
W_LOD_PLAIN		30 Linear	$y = 0.1823 x + 1.2093$	0.219
	1961 to 1991	Quadratic	$y = 0.0002 x^2 - 0.0986 x + 78.057$	0.2463

We exemplify one of these relationships below:

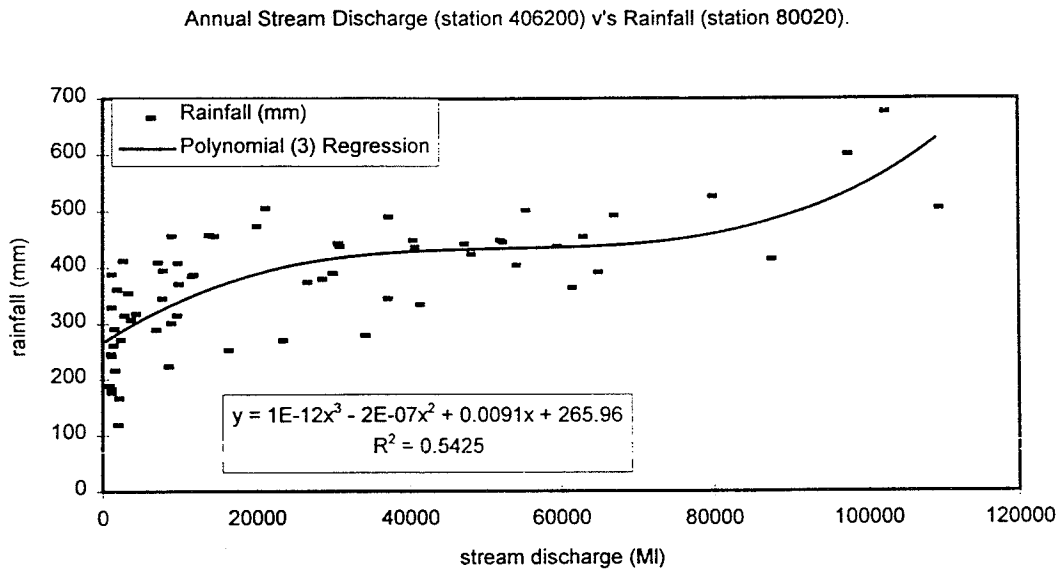


VI. Rainfall/stream discharge relationships by subcatchment

Surface water discharge from all available gauging stations within the Loddon-Campaspe system were plotted against rainfall, and linear and nonlinear regressions were developed for the following station pairs. Note that in some cases the gauging station was associated with more than one nearby rainfall station.

Annual stream discharge	Rainfall
406200	80020
406200	88042
406208	81014
406208	88012
406213	80095
406213	88051
406214	80044
406217	80044
406219	80095
406219	81083
406224	81016
406225	80095
406225	81083
406250	80020
407213	77022
406214	80044
406214	81083
406216	81086
406217	80044
406217	81086
406219	81083
406262	75086
40626	81086

An example of this relationship is given below:



VII. Salt Load/streamflow relationships by gauged catchment

One of the techniques by which groundwater discharge to streams may be estimated is the separation of the stream hydrograph into a baseflow component on the basis of salt loads and concentrations. This inference is useful in the calibration of a groundwater flow net model such as described below.

Salt load versus stream discharge analyses were carried out for the following stations:

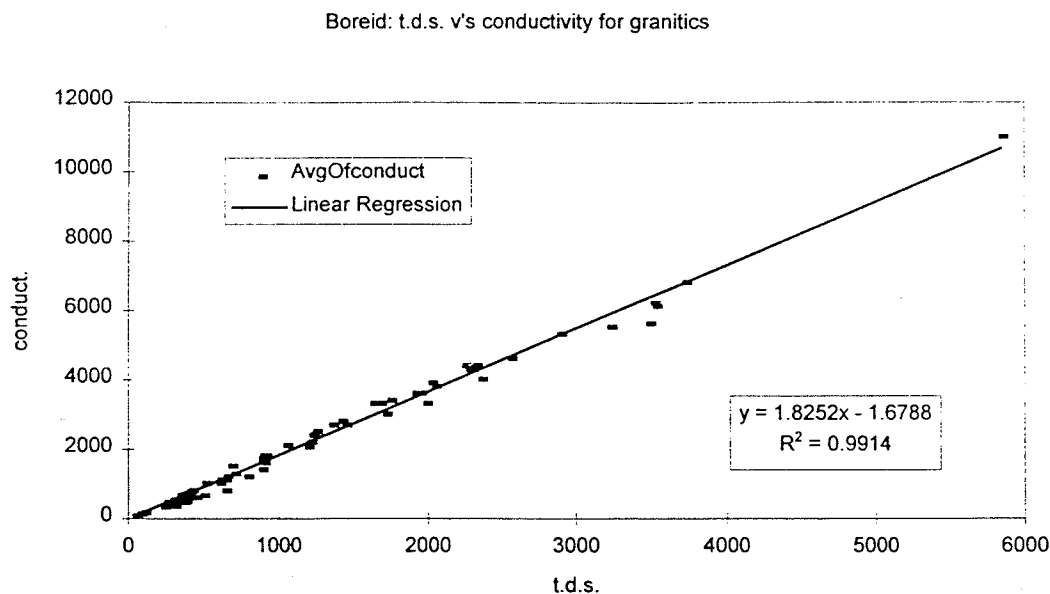
- | | |
|-----------------------------|------------------------------|
| Axe Creek station 406216 | Axe Creek station 406262 |
| Axe Creek station 406214 | Bendigo Myers station 407288 |
| Betbet Crk station 407211 | Camel_Rng station 406224 |
| Middle_Joyce station 407229 | Up_Campaspe station 406213 |
| Wild_Duck station 406235 | |

The first step in this process is to relate electrical conductivity of the stream (the quantity monitored) to the total dissolved solids (salt load) as estimated from bores. The reasoning here is that groundwater of that salinity should form the baseflow component of the stream hydrograph. This analysis was performed on the basis of landscape classifications by geology and subcatchment.

Relationship between conductivity and TDS for the major geological formations:

geology	Number of bores	Regress. equ.	R ²	Regress. c	Regress. b
al	443	$y = 1.4877x + 280.47$	0.9914	1.4877	280.47
fr	23	$y = 1.6171x - 285.52$	0.9739	1.6171	-285.52
gr	73	$y = 1.8252x - 1.6788$	0.9914	1.8252	-1.6788
sf	564	$y = 1.4534x + 98.266$	0.9836	1.4534	98.266
vp	647	$y = 1.4596x + 81.125$	0.9651	1.4596	81.125

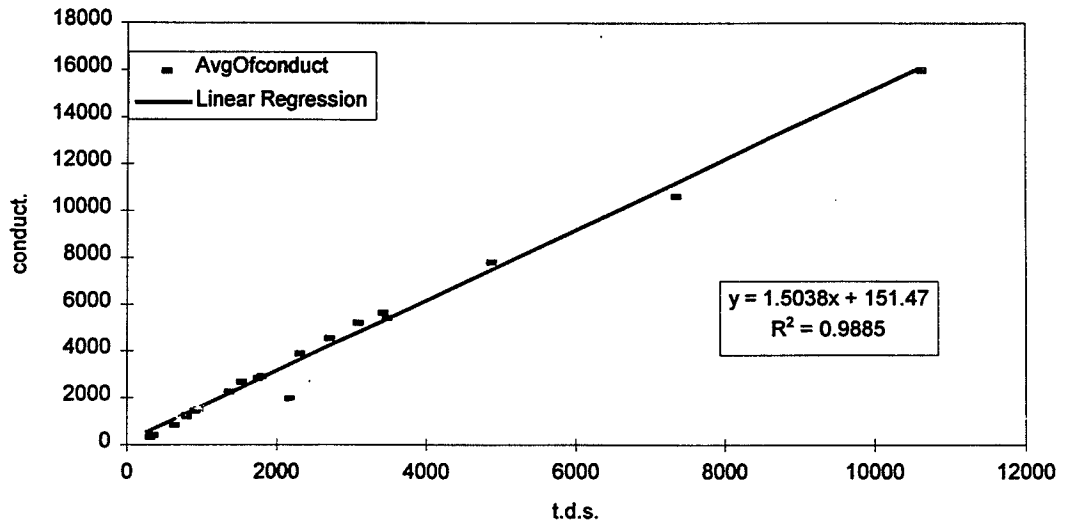
For example, the relationship between tds and ec for bores within granitic geology was as follows:



Similarly, the relationship was developed for most of the subcatchments:

subcatch	Number of Bores	Regress. equ.	R ²	Regress. a	Regress. b
AXE_CREEK	16	$y = 1.481x + 271.72$	0.9901	1.481	271.72
BENDIGO_MYERS	70	$y = 1.448x + 642.38$	0.9915	1.448	642.38
BETBET_CRK	20	$y = 1.5038x + 151.47$	0.9885	1.5038	151.47
BULLABUL	18	$y = 1.4512x + 254.72$	0.9953	1.4512	254.72
CAMP_PLAIN	186	$y = 1.4971x + 172.39$	0.9889	1.4971	172.39
E_LOD_PLAIN	15	$y = 1.4437x + 433.22$	0.9976	1.4437	433.22
FOREST	10	$y = 1.3702x + 557.67$	0.9761	1.3702	557.67
KING_KORONG	7	$y = 1.6115x - 61.227$	0.9908	1.6115	-61.227
LOW_COLIBAN	95	$y = 1.7297x - 103.6$	0.9715	1.7297	-103.6
MCIVOR	15	$y = 1.4389x + 260.51$	0.9885	1.4389	260.51
MID_LODDON	72	$y = 1.5233x + 167.66$	0.9852	1.5233	167.66
MIDDLE_JOYCE	46	$y = 1.5001x + 52.99$	0.9602	1.5001	52.99
MYRTLE	4	$y = 1.9352x - 255.66$	0.9934	1.9352	-255.66
PIPERS	14	$y = 2.1433x - 256.09$	0.9722	2.1433	-256.09
TULLAROOP_CREEK	320	$y = 1.6499x - 48.947$	0.9785	1.6499	-48.947
UP_CAMPASPE	347	$y = 1.381x + 217.75$	0.9646	1.381	217.75
UP_COLIBAN	72	$y = 1.5589x - 18.419$	0.9597	1.5589	-18.419
UP_LODDON	288	$y = 1.393x + 14.992$	0.9582	1.393	14.992
W_LOD_PLAIN	119	$y = 1.4906x + 330.62$	0.9842	1.4906	330.62
WILD_DUCK	10	$y = 1.6432x - 46.061$	0.9983	1.6432	-46.061

Boreid: t.d.s. v's conductivity for subcatchment BETBET_CRK.



The chemical constituents of each bore, and by geology and subcatchment, were also collated and analysed to isolate groundwater systems delivering discharge as baseflow.

Range of chemical constituents (tds in mg l^{-1} and ec in μSm^{-1}) by geology. AL = alluvium, DL = deep lead, Fr = fractured rock, Gr = granitics, Vp = volcanics.

AL	Min	Max
EC	200	12600
TDS	155	8837
Cl	37	3610
Na	34	2404
Mg	5	405

DL	Min	Max
EC	79	24590
TDS	100	14340
Cl	8	6300
Na	9	3609
Mg	3	850

FR	Min	Max
EC	79	32000
TDS	69	20471
Cl	7	11000
Na	8	6200
Mg	1	1218

GR	Min	Max
EC	160	15000

TDS	97	9515
Cl	26	4700
Na	28	2900
Mg	1	570

SF	Min	Max
----	-----	-----

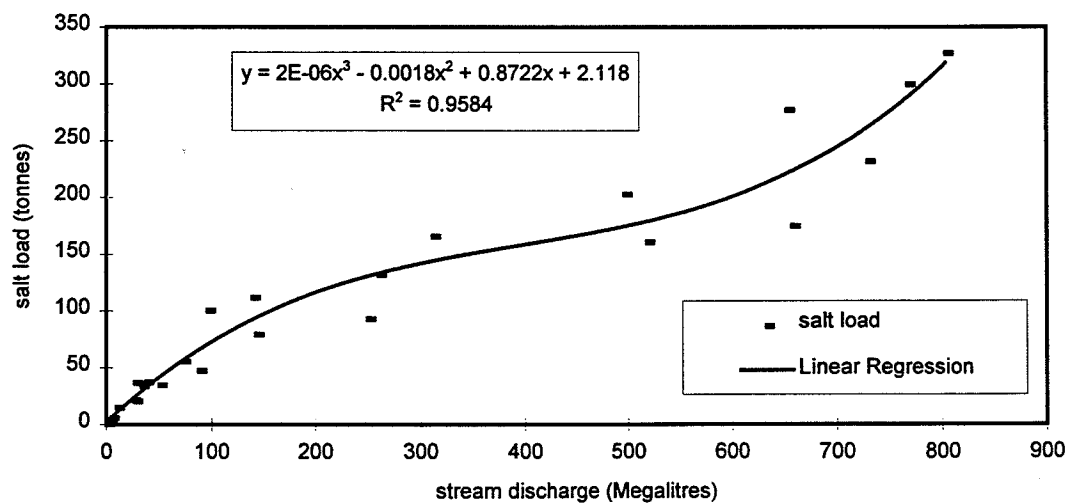
EC	340	34730
TDS	229	20290
Cl	63	10000
Na	40	5400
Mg	5	810

VP	Min	Max
----	-----	-----

EC	77	13000
TDS	41	8927
Cl	7	4100
Na	8	2300
Mg	2	530

These relationships were also used to calculate salt loads from each gauged subcatchment:

Monthly Stream Discharge v's Salt Load for subcatchment Axe_Creek (station 406216).



VIII. Hydrogeomorphic and Flownet Analysis of Loddon-Campaspe Region

The above data and analyses may seem, at first glance, disjunct, but they are all aimed at developing groundwater levels, aquifer parameters and hydrologic responses in support of the modelling of the Loddon-Campaspe system within a hydrogeomorphically-based, steady-state flownet framework.

A. The Discharge Results

As indicated below, the hydrogeomorphic units and the parameters for their genesis are documented within the database, as shown. These were used as the basis for distributing the above regression relationships for surface elevation/hydraulic head surface. These surfaces were used as input into flow net models for 22 subcatchments of the Loddon-Campaspe system.

Due to the requirements of the surface-fitting logic of the flow net analysis, some of these 22 subcatchments were further divided into watershed units to eliminate topological features potentially causing uncertainties in the spline-fitting polynomial function. This resulted in a total of 40 "subcatchments" in the flow net analyses. In some cases these subcatchments are not entirely defined by a zero flux topographic boundary but rather may have boundaries in part defined by a river or channel.

For each subcatchment, four discharge estimation techniques were applied, subject to data availability. These were: groundwater saltload inferences; Darcy's method ($Q = tiw$); vertical recharge/discharge estimation based on WAVES modelling; and FLOWNET estimations.

	Method	Catchment Discharge (Million Metres ³ /yr)				Flownet
		Salt load	Darcy	Vertical recharge (Waves)	Flownet	
Regions	file name	q = load/conc	q = tiw	max	average	
LODDON	lodr			289	53.0	53.2
CAMPASPE	camr			203	56.3	54.5
Subcatchments, Campaspe						
Axe Creek	axe	2.7	2.6	4.5	0.8	2.3
Campaspe Plains	camp	-	2.2	14.5	2.3	6.5
Campaspe Upper	ucam	22.0	14.6	50.0	14.3	11.2
Camel Range	camel	0.5	2.6	11.4	2.4	7.2
Coliban Lower	coli	-	10.9	37.1	10.0	11.0
Coliban Upper	ucoli	12.0	13.7	41.9	15.5	15.6
Forest	for	0.15	1.6	8.9	1.8	2.2
Mc Ivor	mcv	0.81	1.03	4.1	1.0	1.09
Mosquito	mosq	-	0.26	0.5	0.05	0.81
Myrtle	mlt	1.44	1.7	5.8	1.4	0.28
Pipers	pip	5.75	5.7	14.3	4.2	6.8
Wild Duck	wild	8.6	2.7	11.5	2.8	2.3
Subcatchments, Loddon						
Bendigo -Myers	bm	9.9	11.8	39.9	6.2	5.6
Bet Bet	bet	4.7	3.8	15.2	3.4	3.7
Bullabul	bul	-	3.7	4.2	1.0	3.6
King-Korong	king	-	4.1	14.5	3.8	4.5
East Loddon Plains	elp	-	2.7	13.5	1.9	2.2
West Loddon Plains	wlp	-	2.03	13.3	2.7	1.43
Middle Loddon	mlod	1.8	6.3	13.3	2.8	3.4
Middle-Joyce	joy	5.4	5.7	17.6	4.5	5.2
Tullaroop Creek	tull	61.5	12.06	7.3	2	2.7
Upper Loddon	ulod	22.2	21.8	83.8	25.1	14.9

B. Description of directory structure and files produced.

The workspace used for the above Flownet work was structured as follows

```

/transfer_____ /data   common data sets.
    |
    |_/scripts directory of a analysis scripts
    |
    |_/catchment workspaces. Each catchment directory
    |   contains all files produced for hgu and flownet
    |   analysis.
  
```

To use the scripts and perform analysis within the GIS environment the following UNIX environment variables must be set.

```

TRAN      installation_path/transfer
DATA      $TRAN/data
  
```

Also the AMLPATH variable must be set to \$TRAN/scripts

The DATA directory.

This directory houses data sets common to all the catchments. Analysis AMLs may be written to access these grids while working on specific catchments through a catchment mask.

There are five grids in this directory

Grid	description
lc_ridges	grid of ridge lines.
streamexp	grid of major streams.
rec_cls1	vertical component of recharge (Waves modelling)
ramsis_rech	lateral estimates of recharge.
rech_cls2	if (rec_cls1 + ramsis_rech) < 30 else set to 30

The SCRIPTS directory.

This directory houses scripts and utilities used to analysis digital elevation models create groundwater surfaces and prepare data for flownet analysis; this process is described in *HARSD: Procedures and Approaches to Landscape Classification and Groundwater Level Mapping* (CSIRO Division of Water Resources Technical Memorandum). The following scripts are housed in this directory:

Name	Function	author
demstat.aml	generates percentage area statistics for a variety of DEM derived surfaces.	Lin Ye
hga1.aml	plots a4 size maps of specified map themes with overlaid cross-section transects	pdyce
hga2.aml	plots cross sections of elevation, slope, curvature, and break of slope for a given catchment and transect	pdyce
hgu.aml	creates hgu maps and class statistics for a catchment using up to three DEM derived surfaces.	Lin Ye
class.aml	subroutine of hgu.aml	Lin Ye
class2.aml	subroutine of hgu.aml	Lin Ye
class3.aml	subroutine of hgu.aml	Lin Ye
dissolve_2.aml	subroutine of hgu.aml	Lin Ye
killer.aml	AML that prompts user for grids and coverages to deleted	pdyce
tanwl.aml	generates waterlevel maps using $wl = dem - dem * P * \ln(\tan(\text{slope}) * 1000)$	pdyce
surftest.aml	displays any number of groundwater surfaces relative to the original DEM	
samgrid	creates a Flownet recharge.dat file from a reference grid for a specified catchment.	pdyce
dumpgw.aml	exports surface from GRID to Flownet format files	pdyce
loadflow.aml	imports Flownet results to ARC coverages using original groundwater surface grid as a spatial reference	pdyce

The Catchment Workspaces

Each catchment has a separate workspace containing all the files used to do the analysis.

The TULLAROOP catchment is used here as an example file listing. All other catchment directories have the same files. The file name prefix will however alter according to the name of the catchment.

Catchment file listing

File	Description
tullx1:	profile transect coverage
tullx2:	profile transect coverage
tullx3:	profile transect coverage
tullx1:	profile transect coverage
tullx_all:	all profile transects coverage
tullinunitp:	intermediate file - catchment boundary polygon - cartesian coordinates
tullinunit:	intermediate file - water level grid linear regression method - cartesian coordinates
tullincon:	water level contour coverage - linear regression
tullin:	water level grid linear regression method
tullin.aml	AML that produces the water level grid - linear regression method
tull_veg:	vegetation grid
tull_str:	stream coverage (line)
tull_slp:	slope grid
tull_lk:	lake coverage (polygon)
tull_geo:	geology grid
tull_dem:	digital elevation model
tull_cur:	combined curvature grid
tull_con:	contour coverage of DEM
tull_cat:	catchment mask grid
tull_bos:	break of slope grid
tull_bor:	bore location coverage (point)
tull_bnd:	catchment boundary coverage (polygon)
tull.flx	Flownet flux output (ascii)
tran_dat.dat	Flownet fitted transmissivity file (ascii)
surf.file	surface stack file used for stackprofile operations (ascii)
stream.txt	Flownet output - flow lines
slp_9p:	polygon coverage of hgu classification based upon 9 slope classes. (polygon)
slp_9f:	hgu classification based upon 9 slope classes (simplified grid)
slp_9:	hgu classification based upon 9 slope classes (grid)
slp_9.file	hgu classification statistics for hgu classification based upon 9 slope classes (ascii)
slp_9.class	hgu classification description for hgu classification based upon 9 slope classes (ascii)
slp.rmp	slope remap table (ascii)
slp.key	slope key file (ascii)
recharge.dat	Flownet recharge matrix produced from recharge grid and samgrid.aml(ascii)
psfile.zip	postscript files, pkzip archive
catchment.zip	All Flownet .dat files pkzip archive
inoue.dat	Inoue smoothing routine parameter file
init.dat	invers routine parameter file
info:	INFO directory
headobs.dat	Flownet head observation file
head.txt	head contour file - output from the Flownet modelling
ele_wlcon:	Water level contour map for the grid ele_6wl
ele_6p:	coverage of hgu classification based upon 6 elevation classes. (polygon)
ele_6fwlunit:	intermediate file - catchment boundary polygon - cartesian coordinates
ele_6fwlunit:	intermediate file - water level grid linear regression method - cartesian coords

File	Description
ele_6fwlstr:	Flownet flow lines imported back into ARCINFO
ele_6fwlhd:	Flownet head lines imported back into ARCINFO
ele_6fwl:	water level grid hgu from 6 elevation classes.
ele_6fwl.bnd	intermediate file- ascii dump of waterlevel grid boundary
ele_6fwl.asc	intermediate file- ascii dump of waterlevel grid values
ele_6f:	hgu classification based on 6 elevation classes. (simplified grid)
ele_6:	hgu classification based on 6 elevation classes.(grid)
ele_6.file	hgu classification statistics for hgu classification based upon 6 elevation classes (ascii)
ele_6.class	hgu classification description for hgu classification based upon 6 elevation classes (ascii)
ele_3p:	coverage of hgu classification based upon 3 elevation classes. (polygon)
ele_3f:	hgu classification based on 3 elevation classes. (simplified grid)
ele_3:	hgu classification based on 3 elevation classes.(grid)
ele_3.file	hgu classification statistics for hgu classification based upon 3 elevation classes (ascii)
ele_3.class	hgu classification description for hgu classification based upon 3 elevation classes (ascii)
draw.dat	File with the Flownet starting point (defined on screen by a pointing device)
dem.slp	demstat.aml output of slope statistics (ascii)
dem.rmp	dem remap table (ascii)
dem.key	dem key file (ascii)
dem.ele	demstat.aml output of elevation statistics (ascii)
cur.rmp	curvature remap table
cur.key	curvature key file
bound.dat	flownet boundary file (output from boulder)
bos.rmp	break of slope remap table
bos.key	break of slope key file.

IX. References

Dawes, W.R., T.J. Hatton, L. Zhang and T.R. McVicar (1996) Estimating regional scale recharge using the WAVES model in the Loddon-Campaspe. (for submission to the Australian Journal of Soil and Water Conservation).

McVicar, T.R., D.L.B. Jupp. P.H. Reece and N.A. Williams (1996) Relating LANDSAT TM vegetation indices to *in situ* leaf area index measurements.

Heislars, D. (1992). Groundwater in the central Victorian highlands. Water Division, Department of Conservation and Natural Resources, Report Number 87. 196pp.

